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NIS 69

BK2

NATIONAL INTELLIGENCE SURVEY

ANTARCTICA

#0023

SECTION 23

CLIMATE

APPROVED FOR RELEASE
BY: DI/IRo
DATE: 31 MAY 1990

CENTRAL INTELLIGENCE AGENCY

Washington, D. C.

#0023

CHAPTER II

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W A R N I N G

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23. Climate

A. Climatic controls

1. General

The Antarctic is one of the coldest regions in the world with a recorded absolute minimum of -83° F. Although two regions in the Northern Hemisphere have recorded colder winters, the Antarctic interior is considered to be the coldest region in the world during summer. The continental influence of Antarctica is marked not only by its size (almost twice that of the United States) but also by its altitude (average height above mean sea level is 6,000 ft. compared with 2,000 ft. for the average height of all continents). The cold winter weather, largely induced by continental influences but intensified by a minimum of solar insolation and a maximum of radiational cooling in the relatively dry interior, is sufficient to increase the ice coverage in the seas surrounding Antarctica by an area of approximately 6,450,000 square miles, or 1.2 times the total area of the Antarctic continent.

There is a vast expanse of relatively warm ocean surrounding Antarctica, ranging in extent from 600 miles* to the nearest continent (South America) to points north of the Equator in many localities. The Equator is approximately 4,200 miles from the coast of Antarctica. As a result of the abrupt change from polar continental to polar maritime and tropical maritime conditions, the marine portion of the NIS 69 Area** is located in the most persistently strong westerly wind belt (the screeching fifties and sixties) in the world. Both the Antarctic front (the boundary between polar continental and polar maritime air) and the polar front (the boundary between polar maritime and tropical maritime air) delineate regions of relatively intense and frequent cyclonic activity in the marine portion of this Area throughout the year. Only in the eastern portions of oceanic regions in the extreme northern part of the Area is there any trace of the generally mild weather characteristic of tropical *highs*. The direct influence of the subtropical *highs* is most frequent in summer*** when

* Throughout SECTION 23, distances are given in nautical miles.

** The northern boundary of the NIS 69 Area has been extended to 50° S. for SECTION 23.

*** Summer is defined as the three warmest months of the year, the period December through February, and winter includes the three coldest months of the year, the period June through August.

there is a general poleward displacement of all the primary weather controls, the Antarctic *high*, the region of westerlies, and the subtropical *highs*.

2. Pressure distribution

The air circulation in the Area is in general zonal; pressure systems have a greater tendency to move west-east than south-north. The polar easterly and westerly wind belts are also zonal. As a result of the relatively small extent of latitudinal exchange of air, the seasonal changes are not as marked as in the Northern Hemisphere. Cold air masses are quickly modified by the relatively warm waters of the Antarctic seas. In contrast, Arctic and polar air masses of the Northern Hemisphere can emanate from the Arctic southward over continental regions into the United States, southern Europe, and southern Asia before there is complete air mass modification. Charts showing the mean pressure distribution in February and August over the Southern Hemisphere are presented in FIGURES 23-1 and 23-2. Since these charts are intended to emphasize only the general location of pressure systems, the day-to-day influence of migratory systems is obscured.

Because of the tendency for zonal movement of pressure systems in the Southern Hemisphere, the semipermanent low-pressure belt is elongated in such a manner that a single *low* center stretches most of the way around the world usually between 60° and 70° S. This low-pressure zone is located in the convergence area between the surface high-pressure region of the Antarctic and the warm subtropical high-pressure cells centered in the three major oceans north of the Area.

The nearest semblance in the Southern Hemisphere to the semipermanent *lows* of the type found in the vicinity of the Aleutians or Iceland are the low-pressure regions of the Weddell and Ross Seas. These *lows*, however, are not as well defined as their counterparts in the Northern Hemisphere.

The presence of high-pressure regions north of the Area is reflected throughout the year by a general northward decrease in mean wind speeds and an overall amelioration of weather conditions. The mean sea-level pressure charts show similar trends and patterns in all three oceans. The South Indian, South Atlantic, and South Pacific *highs* are centered 1,080, 1,260, and 1,200 miles, respectively, north of the Area in February and 1,200, 1,620, and 1,500 miles north of the Area in August. The

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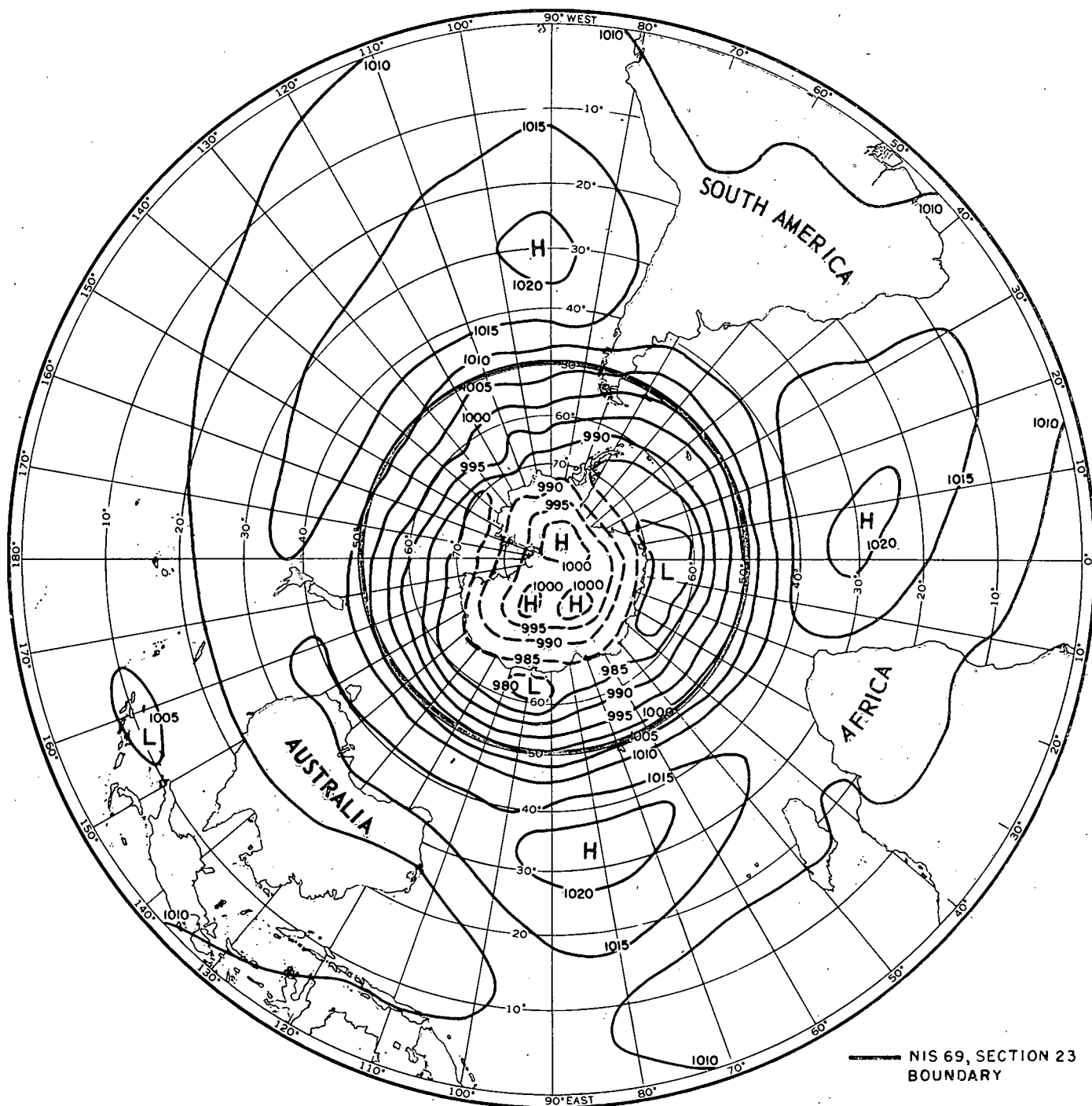


FIGURE 23-1. MEAN SEA LEVEL PRESSURE (MILLIBARS), FEBRUARY

South Indian *high* tends to dominate the central portion of its ocean throughout the year. The South Atlantic and South Pacific *highs*, on the other hand, tend to dominate the eastern portions of their oceanic basins in summer. In winter the influence of both of these *highs* is displaced westward to some extent.

In many respects the region dominated by the Antarctic or polar *high* approximates the territory south of the pack-ice limits. The polar *high*, most readily recognized by the prevalence at the surface of easterly or southerly winds, generally is found

south of 65°S. throughout the year and as far north as 55°S. in winter. However, in the Ross and Weddell Sea regions, the polar *high* is usually south of 68°S. Since 1895 when explorers first recognized that Antarctica was dominated by a *high*, there have been considerable differences in opinion concerning the nature of this *high*. The shift in wind direction from easterly and southerly at the surface to westerly and northwesterly aloft indicates the presence of a cold *high* at the surface and a cold *low* aloft. This atmospheric structure was first based on smoke observations of the active volcano

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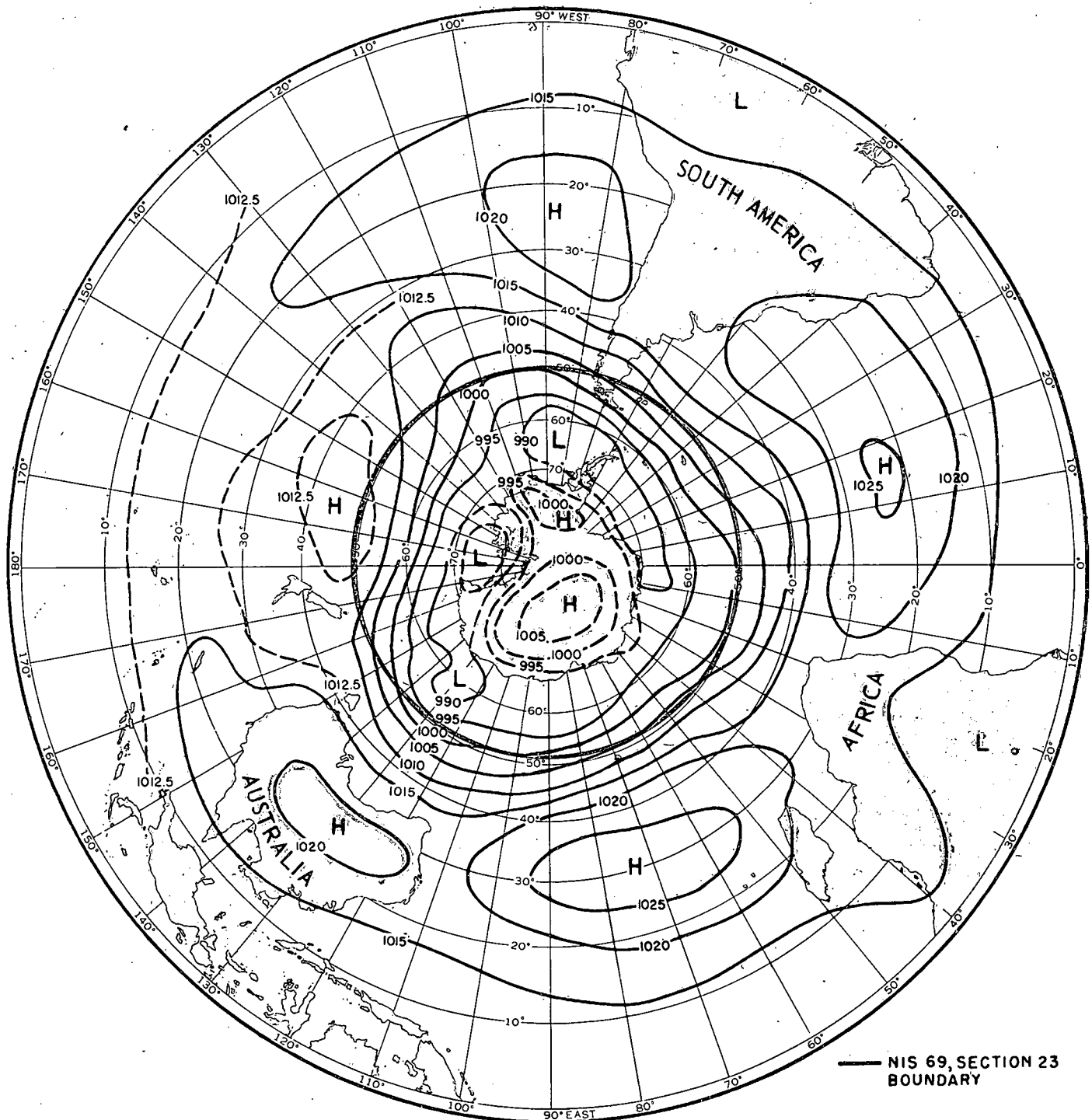
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FIGURE 23-2. MEAN SEA LEVEL PRESSURE (MILLIBARS), AUGUST

Mount Erebus (15)* and later substantiated by upper-air observations made by expeditions since the thirties. Because of the high inland terrain (generally above 6,000 ft.), however, there is considerable speculation as to whether a cold *high* or a cold *low* predominates at the surface. The relatively low frequency of surface *lows* over the Ant-

* Italic numbers in parentheses following place names refer to locations shown on FIGURE 23-28. This figure also shows data evaluation and total observations for the Area.

arctic compared with that frequency typical of the westerlies, the predominance of surface easterlies and southerlies along the coastal regions of Antarctica, and the high frequency of foehn gales in the vicinity of coastal valleys indicate the presence of cold high-pressure conditions at the surface in the interior. The occasional stretch of clear weather as experienced on the summit plateau by Scott on his last expedition is typical of cold high-pressure conditions. However, the wind shift from southerly or southeasterly to northerly or north-

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westerly accompanied by blizzard conditions is indicative of the presence of a cold *low* at the surface.

During the Byrd expeditions, meteorologists found evidence of the existence over the Antarctic of multiple (two or three) high-pressure regions each with its separate anticyclonic circulation. This premise is substantiated by the fact that a single *high* cell over such a vast area as Antarctica is not probable because mountain barriers divide the Antarctic into three separate regions. High pressure dominates the region known as Marie Byrd Land, with a ridge extending along the Palmer Peninsula; the region south of Wilkes Land; and the region south of Queen Maud Land, where the *high* appears in the form of a transitory and semi-permanent wedge. As a result of the general location of these high-pressure regions, it is natural to expect the highest frequency of polar outbreaks either north of Marie Byrd Land and west of the Palmer Peninsula, or north of Wilkes Land and west of the Ross Sea.

3. Air masses and zones of interaction

a. AIR MASSES — The air masses within the Area could be stated simply as continental over the continent and pack ice and maritime over the ocean regions. Although this is true, further explanation is necessary because of the topography of Antarctica. Antarctica is primarily a 6,000-foot plateau surrounded by pack ice, whose surface varies in extent from month to month and year to year.

(1) *Polar continental air* — A cold dry polar continental (*cP*) air mass lies over the plateau of Antarctica. It is characterized by a surface inversion, which is shallow in summer and extends up to 3,000 ft. in winter, and a normal lapse rate above the surface layer. In the Ross Sea region it has been found that the depth of the continental air mass is inversely proportional to the distance of the Antarctic front from the continent. For example, when the front is 150 miles from the continent the depth of the polar air mass is about 8,000 to 10,000 ft., but when the front is 200 to 300 miles distant the depth of the air mass is about 4,000 to 6,000 ft.

(2) *Antarctic continental air* — As a *cP* air mass moves seaward, it becomes modified to Antarctic continental (*cA*) through subsidence and surface heating. By the time it reaches the solid pack ice, the lower levels of the *cA* air mass approach a dry adiabatic lapse rate. The depth of this layer varies from 1,000 to 2,000 ft. to as much as 4,000 to 5,000 ft. depending on the width of the pack ice. A slight amount of moisture is acquired in the surface layer but it is insufficient to raise the relative humidity generally to more than 50% or 60%. An inversion of 2° to 5°C. exists immediately above this layer of *cA* air, and a slightly stable

lapse rate prevails from this inversion to the frontal surface bounded by polar maritime air. However, the strength of the inversion and the character of the lapse rate above varies depending upon converging or diverging airflow. Cyclonic flow produces an inversion which is smaller and more nearly isothermal with a moist adiabatic lapse rate associated with the overrunning polar maritime air. Anticyclonic flow results in a relatively large and deep inversion with a pronounced stable lapse rate.

(3) *Antarctic maritime air* — When the Antarctic continental air passes over water, it is modified to form Antarctic maritime (*mA*) air. The term *mA* was applied by naval units operating in the Antarctic area to fit an air mass intermediate between polar continental (*cP*) and that normally termed polar maritime (*mP*). Antarctic maritime (*mA*) describes Antarctic continental (*cA*) air that has been modified by a relatively short water trajectory, usually 50 to 100 miles minimum and up to 500 miles maximum, beyond which it assumes properties similar to fresh *mP* air. The Antarctic front marks the northern boundary of this *cA* or *mA* air mass. The acquisition of moisture to the *cA* air can result from advection over open water between fast ice and pack ice, rotten pack ice, openings, small bays, and the open sea. The addition of moisture below the inversion manifests itself in the formation of fractocumulus clouds, which thicken into stratocumulus and finally develop vertically. The degree of development depends, of course, on the amount of overwater travel. Antarctic maritime air exists primarily in wedges extending northward from the Antarctic anticyclone, in bubble *highs* developing from the wedges, and in flow (migratory *highs*) paralleling the continent north of the pack ice over the sea.

(4) *Polar maritime air* — Polar maritime air (*mP*) lies north of the Antarctic front in the broad subantarctic oceanic zone between the Antarctic and approximately 45°S. Such air first enters this region of cold oceanic currents and massive floating ice either from the Antarctic or from the subtropical *highs* of the three oceans. It then acquires the polar maritime characteristics (high moisture content and cold temperatures) after sufficient travel eastward along the isotherms of the sea surface temperature. Polar maritime air is a large homogeneous air mass having a moist adiabatic lapse rate up to 10,000 to 15,000 feet topped by a relatively thin stable layer. In zones of convergence, heavy cumulus clouds develop in the moist layer resulting in snow showers. When the South Atlantic and South Pacific subtropical *highs* are well developed, maritime tropical (*mT*) air enters the outer limits of the Area, bringing with it the undesirable frontal weather of a warm moist air mass engaging maritime polar air.

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b. ZONES OF INTERACTION — The Antarctic front marks the boundary between the continental air mass and the polar maritime air mass of the prevailing westerlies. The front, which is ill defined, has its greatest intensity where the polar easterlies converge with the westerlies. The average location of the Antarctic front is from 50 to 150 miles north of the pack ice, but it can be found as far north as 400 miles. In rare cases it may retreat onto the continent under the influence of an extremely strong northerly circulation.

The Antarctic front acts as a quasi-stationary frontal system bounding the polar continental high, sometimes advancing as a cold front or retreating as a warm front, and it usually marks the boundaries of an eastward moving wedge. The weather along such fronts is similar to that found in the vicinity of normal undeveloped frontal systems in the region of westerlies. The cold front associated with the Antarctic front generally has a line or zone of snow showers or squalls which, if air mass showers are also present, become very dense. A temperature drop of 2° to 3° F. during such a frontal passage is relatively common although as much as a 5° to 7° F. drop has been observed. A noticeable change in air mass characteristics occurs. The warm front associated with the Antarctic front has a well-defined cloud shield. As the warm front advances, an altocumulus cloud layer at 8,000 to 10,000 feet marks the leading edge of the shield, becoming mixed with altostratus as it lowers. Air mass weather, in the form of snow showers usually begins before the snow shield is reached. As a quasi-stationary front, the Antarctic front may combine the characteristics of both a warm and a cold front, depending on the trajectory of the westerlies to the north. With overrunning, there is a narrow band of altocumulus clouds and widely scattered light showers.

The polar front, which marks the boundary between polar maritime and tropical maritime air masses, only rarely penetrates the northern limits of the Area. Generally, the air masses are so well mixed when they reach the northern boundary of the Area that the polar front becomes indefinable.

4. Maritime and continental influences

The most significant topographical features of Antarctica are its vast size, its circular shape, and its relatively high inland altitude. Since Antarctica is completely surrounded by relatively warm water masses, the combination of the continental and maritime conditions in this Area brings about one of the most abrupt climatic transitional zones in the world. Within a distance of 1,200 miles the climate varies from tropical maritime and that of

the temperate Zone in the north to polar continental south of 70°S.

The shortest distance across Antarctica from the Weddell Sea via the geographic South Pole to the Ross Sea is about 1,400 nautical airline miles. The longest distance across the continent from the northern tip of the Palmer Peninsula via the pole to the Shackleton Ice Shelf (3) is about 3,000 nautical airline miles. This vast land mass is sufficiently large to "manufacture" polar air outbreaks which are considerably colder than those experienced in north-central United States during winter. Because of the circular shape of Antarctica, the various weather regimes of this Area occur in concentric bands centered about the South Pole. The variable continental conditions are evident at Little America (7) where mean monthly temperatures are in the minus 40's (°F.) in winter and in the plus 20's (°F.) in summer. Just north of the ice limit the air temperature is generally within a few degrees of freezing throughout the year. The Antarctic front, characterized by strong winds and adverse weather, is generally found within this zone of temperature discontinuity. The moderating influence of the oceanic regions on the extremely cold Antarctic air masses is evident in the offshore regions where the most frequent air temperature throughout the year is in the low 40's (°F.) at 70°S. and in the high 40's (°F.) at 60°S.

Antarctica's steep, jagged coasts and high rolling interior help explain the peculiar, complex surface winds which can vary extremely over short distances. In general the 5,000-foot topographical contour is 60 to 180 miles inland except south of the Ross and Filchner (16) Ice Shelves and south of Wilkes Land where this contour is 250 to 500 miles inland. Cold air in the process of emanating from the interior and manifesting itself as foehn winds in the vicinity of the coast warms up at least 15° F. As a result, the first indication of a blizzard, even when the wind is southerly, is frequently a sudden rise in temperature. Many times such winds develop into blizzards which may be confined to valleys and bays. In one instance calm clear conditions were experienced within 1 mile of a full gale.

The abrupt coastline, especially in the Ross Sea region, has frequently been referred to as the *cloud maker* because of the persistence of heavy low clouds orographically induced by onshore winds. Inland, on the summit plateau, where the generally rolling topography is interspersed with many mountain peaks between 10,000 and 15,000 feet, weather conditions are variable. Fair calm weather is frequently interrupted by overcast spells when gale force winds funnel through mountain passes. As a result, inland valleys are typified by shifting drifts of light dry snow and by hard-

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packed wind-scoured snow surfaces known as sastrugi. Snow-filled crevasses and glacial pressure ridges can create trafficability problems. Since there is a recognized lack of climatological data in the Area, especially in the interior of Antarctica, familiarity with the topographical conditions and their influence on the weather is a necessity.

B. Surface winds

The westerlies and the polar easterlies are the predominant wind systems in this Area. These winds result from the circulation of the Southern Hemisphere subtropical high-pressure regions, the

belt of subpolar migratory lows, and the Antarctic continental polar air masses.

Monthly charts of surface wind roses are presented in FIGURES 23-16 and 23-17. Charts showing the frequency of light winds (Beaufort force 0-3) and gales (Beaufort force 8-12) are presented in FIGURES 23-3 through 23-6 for February, May, August, and November. Wind roses with a double circle indicate smoothing by using statistical tools similar to those developed by C. E. P. Brooks and N. Carruthers. For some of the Area additional data were obtained from daily synoptic weather maps by gradient wind methods.

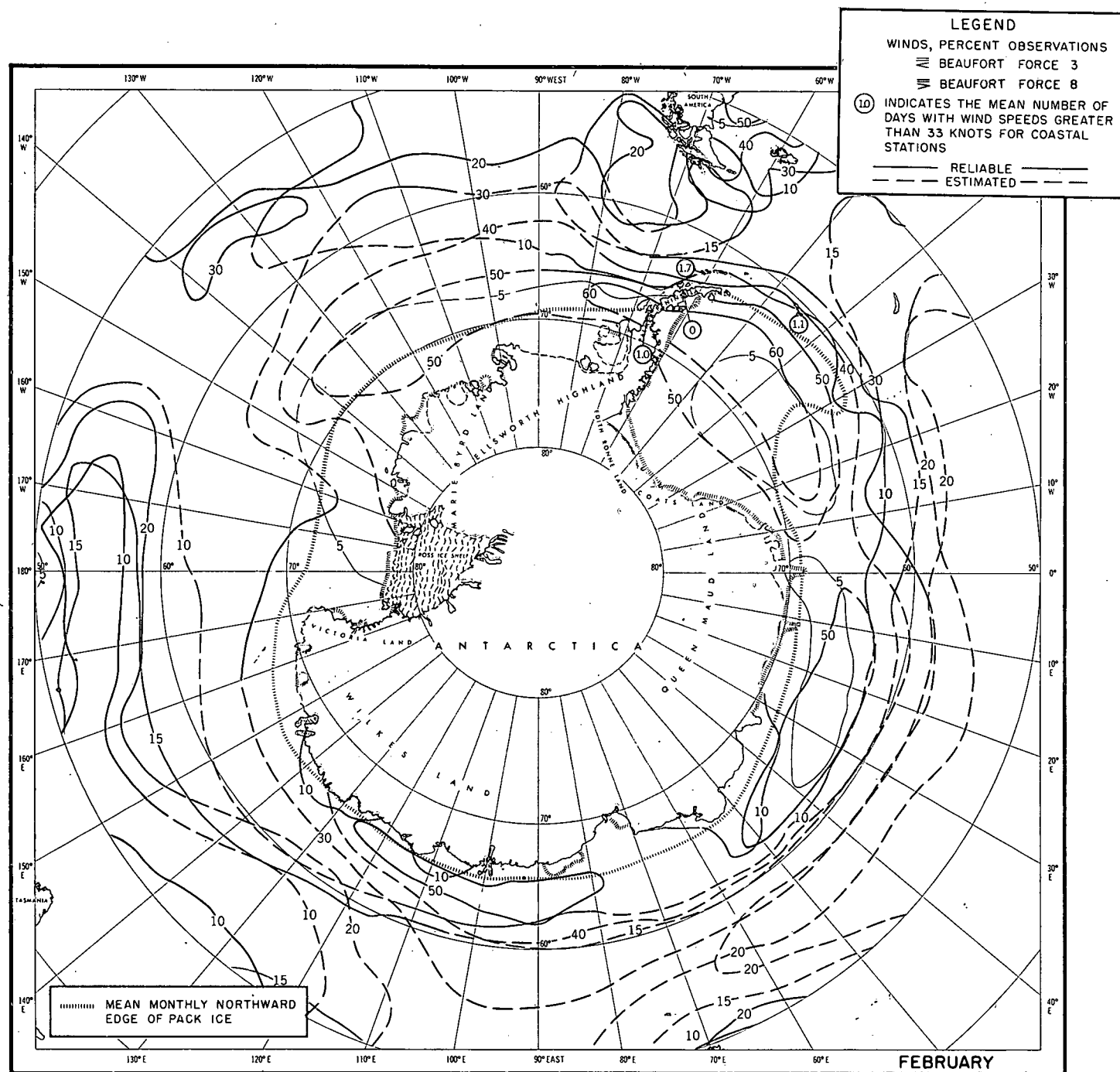


FIGURE 23-3. WINDS $\equiv$ BEAUFORT FORCE 3 AND $\equiv$ BEAUFORT FORCE 8, FEBRUARY

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~~CONFIDENTIAL~~**1. Region of the continental high**

The Antarctic high-pressure areas combine to produce a general easterly component of winds south of 60°S. Although the average winds are moderate in strength, variability and sudden change are characteristic of Antarctica's winds. In contrast to the overall circulation there are many accounts of gale- and hurricane-force winds, of short and long duration, associated with large-scale disturbances and local conditions. These storms are of interest because they are hazardous to surface operations, reducing visibilities in blowing snow and causing turbulent sea conditions over open water.

The easterly winds are most persistent in the region bordering the continent from 20°E. through 150°E. Here, the winds from due east comprise 25% of the observations and when combined with winds from other easterly components average 50%. The average wind speeds are not excessive, being near 15 knots with 5% to 10% frequency of calm or variable winds. Gale-force winds are not infrequent, averaging 10% of the observations.

In the Weddell and Ross Sea areas the easterly winds are not as persistent nor do they influence the circulation as far north. The frequency of cyclones and polar continental air-mass outbreaks through these regions results in increased frequen-

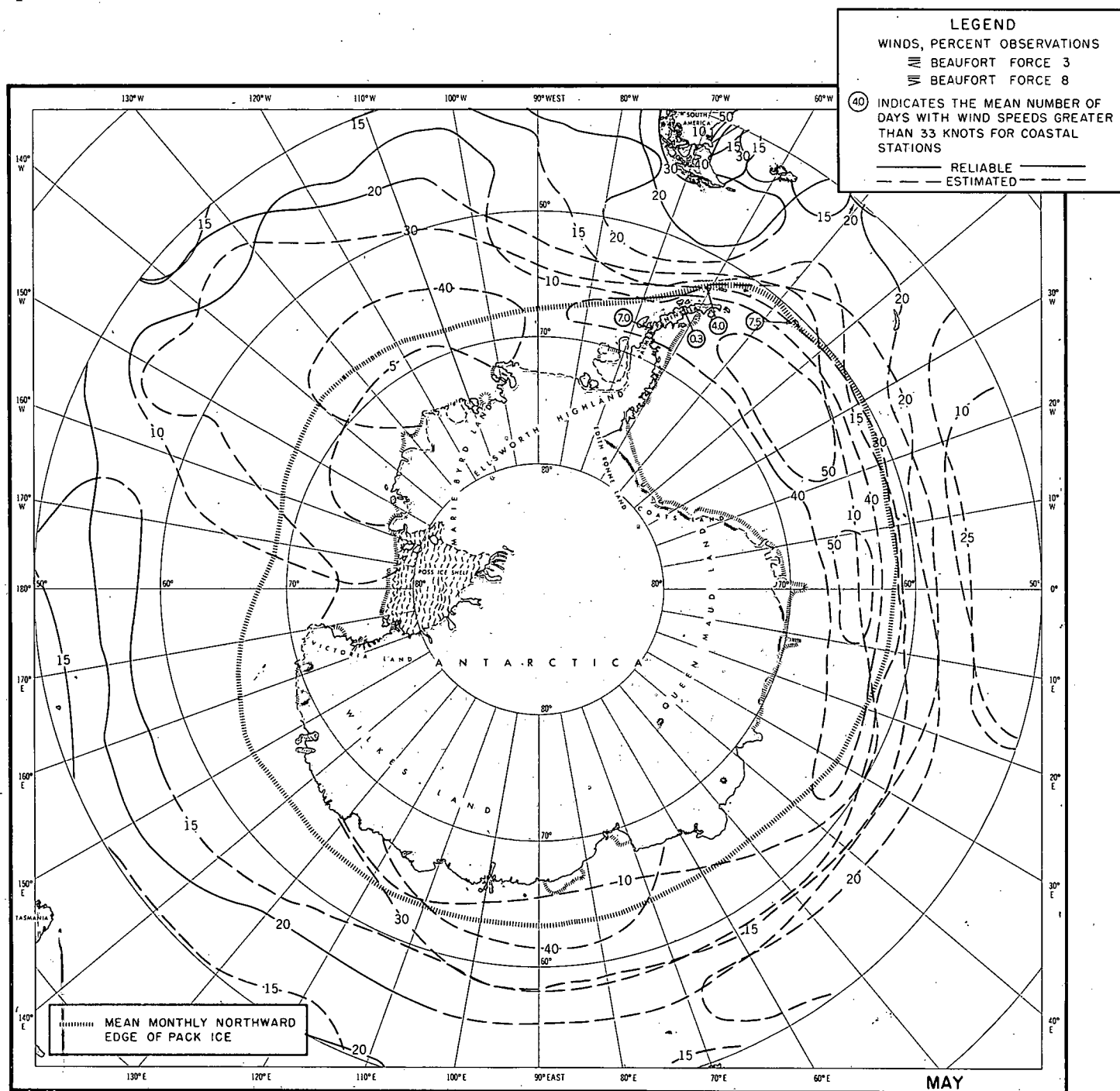


FIGURE 23-4. WINDS ≥ BEAUFORT FORCE 3 AND ≥ BEAUFORT FORCE 8, MAY

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cies of southerly and westerly winds as far south as the 70th parallel. The winds at Little America are mostly from the east, except during the period July through September when they show an increased component from the south and southwest; however, throughout the year the largest monthly percentage of movement is from the east. This increased southerly component during winter is coincident with the maximum northerly displacement of the easterlies and with the season of minimum mean speed.

The leeward (west) side of Palmer Peninsula has a noticeably high percentage of calms and light winds. This is possibly a result of the cold,

stable air becoming trapped in the highly dissected and rugged coastal region.

The interior portions of the continent are influenced by predominantly easterly winds, but they are subject to many local influences of topography. The mean wind speed is similar to that experienced at Little America, which is approximately 8 knots. Local circulations, however, may reach hurricane speeds. Many of these high-speed winds are of the gravity type, which originate as a result of subsidence aloft, surface cooling over the gradual frozen downslope, and a pressure distribution to accelerate the process. The intensity and duration of these drainage-type winds vary with the

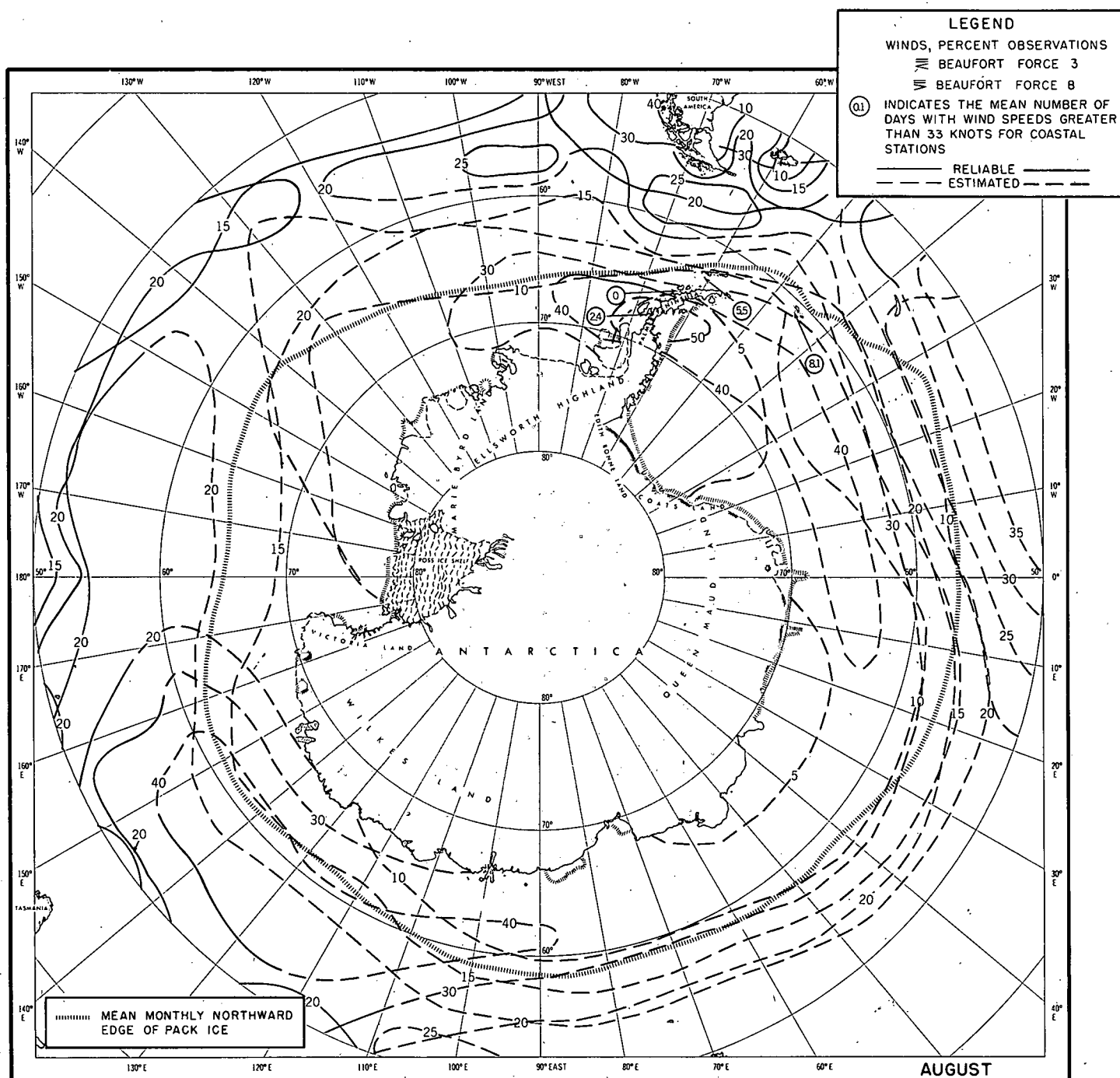


FIGURE 23-5. WINDS $\equiv$ BEAUFORT FORCE 3 AND $- - -$ BEAUFORT FORCE 8, AUGUST

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geographical location and the speed at which the overall circulation pattern moves. Actual observations of 93-knot winds for an 8-hour period, with gusts to 174 knots, were reported by Sir Douglas Mawson in the vicinity of Adélie Coast (4) along the continental edge. The strongest winds of this type are those reaching the open water, especially at the mouths of glaciers; however, they do occur inland with the air draining into valleys through mountain passes. Winds of this type do not penetrate far over the open water or valley floor, because gravity winds are relatively shallow and upon reaching a base level tend to fan out. They usually extend to a maximum of 10 miles from the

shore and are primarily a landing and surface transportation hazard. Gravity winds may occur with little warning and reach gale force in a short period of time. The most frequent occurrence is during winter, but they may occur at any time during the year.

2. Region of the westerlies

The westerlies affect this Area as far south as 60° to 65°S., dipping still farther southward into the Ross and Weddell Seas as a result of the relatively high frequency of extratropical cyclones. Prevailing directions are generally northwest or west with little seasonal variation, and average

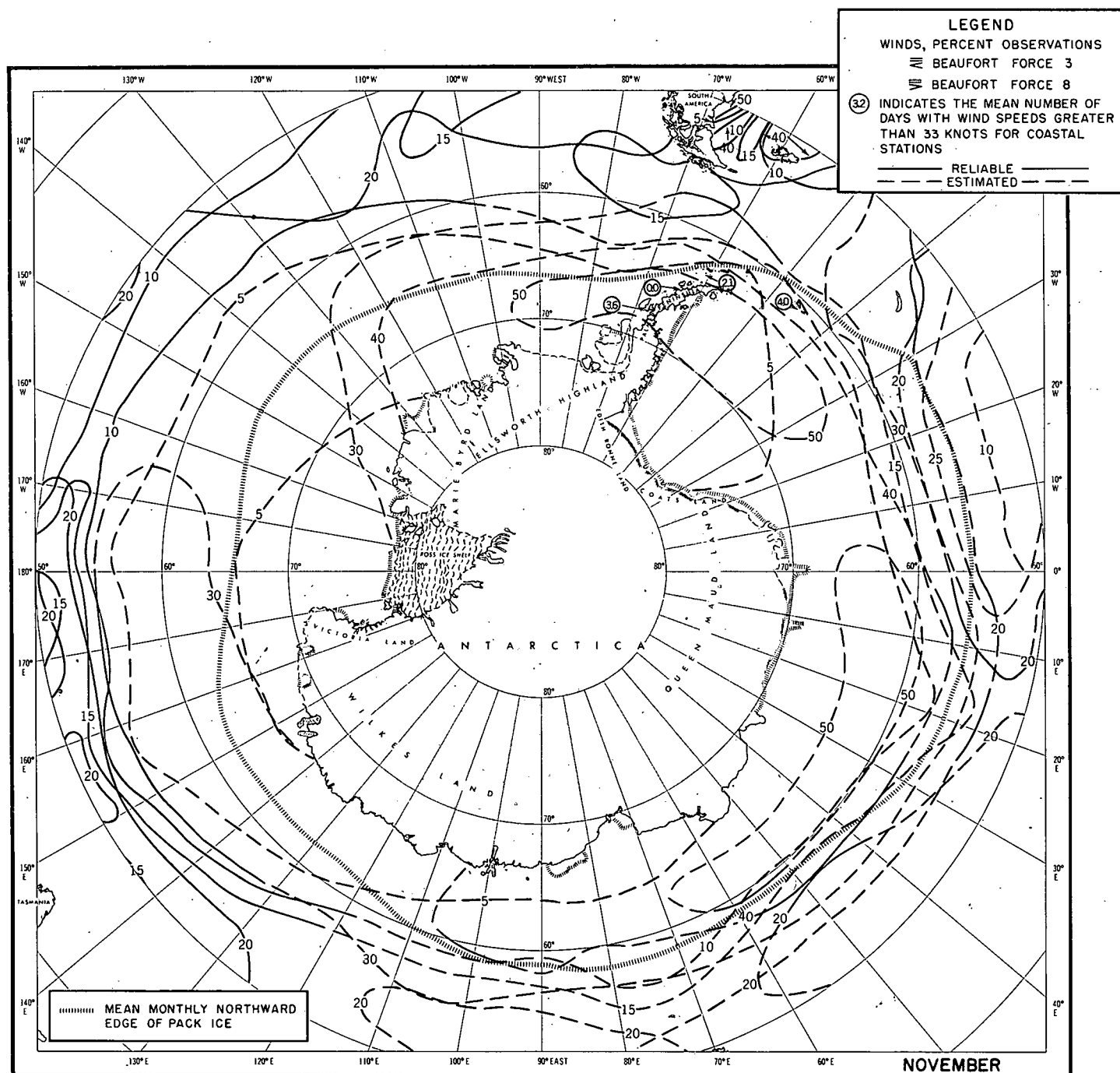


FIGURE 23-6. WINDS — BEAUFORT FORCE 3 AND - - - BEAUFORT FORCE 8, NOVEMBER

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speeds are near 20 knots. The area of maximum strong winds, in general, lies between 50° and 60°S. shifting slightly southward and decreasing in frequency during the warmer half of the year. Strong, gusty winds are characteristic; gales occur frequently, sometimes blowing for several days at a time. The maximum frequencies of gales, 25% to 35% of the observations, occur between 50° and 60°S. along the southern extent of the subtropical high-pressure zones. This high frequency of gales would lessen the operational value of observer aircraft in this zone. The winds are strongest during winter when the frequency of cyclonic storms increases and the intensification of the subtropical high-pressure regions produces steep pressure gradients. The absence of continental obstructions decreases the meridional exchange, thus allowing for maximum development of wind speeds. Since this zone is just north of the ice boundary, rough seas, heavy swells, and structural icing may be expected to affect the operation of ships.

Foehn winds at South Georgia, and other mountainous land areas, sometimes attain hurricane speeds. In 1932 the *Discovery* was blown out of Cumberland Bay (14) by strong winds, but when the ship was 10 miles at sea the weather became calm.

Although the westerlies are weaker during summer, moderate to strong winds are observed over the entire zone. Gales, associated with migratory lows, occur in 20% of the observations. The percent frequency of gales decreases toward the south. Conversely, the frequency of light winds increases toward the south.

C. Surface air temperatures

There are essentially two zones governing the generation and modification of temperatures in the Area, the Antarctic continent together with the ice shelf and the surrounding oceanic region. The extent of the continental source of cold air varies seasonally with a probable maximum in August and minimum in February. Similarly the source of maritime air moves northward as the field of pack ice spreads from Antarctica to roughly beyond the latitude of the South Orkney Islands.

Mean isotherms for February, May, August, and November and cumulative frequency diagrams of temperatures for specified quadrangles are presented in FIGURE 23-18. Because of the steep temperature gradient in the region just north of Antarctica, the interval south of the monthly ice limits was changed from 2° to 5° F. The intersection of the distribution curve with the 5- and 95-percentile lines on the diagrams approximates the mean monthly minimum and maximum tempera-

tures, respectively. It should be noted that because of the variation in temperature limits with latitude, the diagrams do not necessarily include the same temperature range. Cumulative frequency diagrams of air-sea temperature differences are presented for the months February, May, August, and November in FIGURE 23-19. An example of the use of this diagram is seen in the legend, where the intersection of the 80% line with the curve shows that 80% of the time the air temperature was never more than 2° F. warmer than the water.

The air-sea temperature difference gives an indication of the stability expectancy over the ocean areas surrounding Antarctica. Asymmetrical distributions indicate a preponderance of stable or unstable atmospheric conditions, depending on the relative frequency of cold air over warm water or warm air over cold water, respectively. They also serve as a guide to the probable occurrence of fog.

In the construction of the temperature curves, data limitations made it necessary in many cases to supplement November and February observations with December and January data, respectively. In some cases this has decreased the contrast between successive seasons and has led to an apparent discrepancy between median temperatures and mean temperatures as shown by the mean isothermal analysis for any given month.

The isotherm pattern consists almost entirely of closed isolines surrounding the continent. Irregularities in the coastline and ice limits tend to be reflected by the isolines for a considerable distance to the north. That is, lobes in the isotherms follow the ice limits quite closely and present a relatively simple and more or less concentric pattern.

The most obvious deviation from this simple pattern occurs in the Weddell Sea region where a substantial bulge in the isolines is found in all seasons. This is probably due to the combined effects of prevailing winds and currents.

Both gradual and steep gradients occur in all seasons and, in all but exceptional local situations, temperatures increase with decreasing latitude. Tightly packed isolines of sea surface temperatures tend to induce a similar isoline pattern in the mean air temperatures. For example, in Drake Passage where the ocean current flows toward the northeast the relatively short distance between the Palmer Peninsula and Cape Horn causes a bottleneck effect. As a result there is a packing of the sea surface isotherms and, consequently, of the surface air temperatures. In February, the gradient in this region exceeds 2° F. for each degree of latitude. By way of contrast, the gradient on the eastern edge of the Weddell Sea is less than

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one-fourth this figure. Throughout the Area during the winter months there appears to be a general steepening of the gradient, although the mean gradient across Drake Passage remains about the same. The gradient for the southern half of the strait, on the other hand, is steeper than that of the northern half.

Data covering extended periods are not available for interior points on the continent. Even on the periphery only a few stations have been continuously maintained for sufficiently long periods of time to give an approximation of representative temperatures for any given spot. Certain conclusions can be drawn, however, concerning temperature relationships.

Observations taken over extended periods at McMurdo Sound (17) and Little America (7) may be assumed to be fairly representative. Both stations are located within 1° of the same latitude and have somewhat similar positions on the leading edge of the Ross Ice Shelf. Available data for January show mean temperatures within 1° F. of each other, whereas all succeeding months, with the exception of April, show lower mean monthly temperatures at Little America than at McMurdo Sound. The greatest difference occurs in August when the McMurdo Sound mean exceeds the Little America mean by 23.8° F. The average difference for the three summer months is 22.8° F.

Conditions exist which favor the occurrence of colder temperatures at the Little America site. The foehn effect may make some contribution to the higher temperatures at McMurdo Sound. It seems more likely, however, that the prevailing circulation pattern favors the passage of colder air on the eastern side of the Ross Ice Shelf.

A similar condition exists on the Weddell Sea side of the Palmer Peninsula where analysis shows one of the most pronounced lobes in the temperature pattern.

The presence of open water or the distribution of ice and water may account for differences in temperature between two bases that are similarly situated. On the northwest coast of Palmer Peninsula, Port Lockroy (18) and Argentine Islands (19), are separated by a distance of about 40 miles, and yet Port Lockroy averages 4° F. warmer for the year.

The northward extent of the pack ice in winter results in a virtually continuous snow surface. This snow is a relatively cold surface and, at the same time, effectively insulates the atmosphere against the transmission of heat from the underlying water. The lowest temperatures recorded occur over snow surfaces during calm, clear anticyclonic conditions. Low maximum temperatures are the rule throughout the year wherever data

are available. Minimum temperatures over the continent are available only in sporadic locations, but numerous expeditions and short-term stations have reported exceedingly low minimums. In 1911 a minimum of -77° F. was recorded by a sled party on the Ross Ice Shelf near Ross Island. In 1934 at the station occupied by Byrd, 94 miles south of the main base, a minimum of -83° F. was recorded on 21 July 1934.

Diurnal variations for McMurdo Sound were investigated in detail by G. C. Simpson following the last Scott expedition. The diurnal trend was normal except during the daylight hours. Simpson found that during May, June, and July, when the sun was below the horizon continuously, the temperature remained above the daily average from 0900 to 1900 LST. During the remaining hours the temperature fell below average with a pronounced rise at about 0400 LST. This phenomenon has not yet been satisfactorily explained although its occurrence to a greater or lesser degree has been established in other localities.

Forecasting of temperatures in the Antarctic suffers from the usual disadvantage of single-station forecasting. In the water regions, at a distance of greater than 100 miles from the ice shelf, there are much smaller ranges of temperature during all seasons. Persistence is the rule in such regions of limited land masses and continental effects. Over the continent, on the other hand, forecasting can be uncertain because of rapid changes in wind direction as well as foehn and drainage effects. Stations near the water tend to reflect the moderating effect of the maritime influence, and stations subject to foehn winds may experience sudden rises in temperature.

The mean temperature range for Little America in February 1940 was 16.0° F. when the daily ranges varied from a minimum of 4.0° F. to a maximum of 25.6° F. In August the mean range increased to 26.4° F. when the daily ranges varied from a minimum of 15.2° F. to a maximum of 46.3° F.

Extremely cold temperatures can alter the physical characteristics of many materials. For greater detail concerning the influence of temperature on military operations see Subsection I.

Fabrics, one of the few exceptions, remain largely unaffected by subzero temperatures, although certain materials do undergo significant change. Leather, however, becomes stiff and tears easily. If allowed to freeze when wet it is usually ruined. Very cold glass and glazed ceramics may shatter when subjected to a warm blast of air. Copper wiring becomes brittle enough to fail under tension. Steel becomes brittle and should not be handled roughly.

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One of the major problems in the operation of mechanical equipment is the rapid stiffening of lubrication oils. Both OE-10 and OE-30 weight engine oils become solid at -60°F. , and preheat is essential for starting between this temperature and -35°F. Cold gasoline engines may require as much as 2 hours to warm, and diesel engines may require about twice that time.

D. Precipitation

The lightest precipitation in this Area occurs over the Antarctic continent and the amounts increase northward in proportion to the increase in temperature and moisture. Regions of relatively high frequency of occurrence of precipitation do not necessarily coincide with regions of relatively large amounts. For example, even though the frequency of precipitation in the interior of Antarctica may appear moderate, the climate is considered near arid. The precipitation pattern is complicated by Antarctica's mountainous topography surrounded by large sections of ice shelves. These shelves in turn are surrounded by a belt of pack ice of varying width and extent. Also, the convergence areas between the polar easterlies in the vicinity of the continent and the westerlies generally north of 65°S. cause a second precipitation region.

Over the belt of pack ice and over the ice shelves larger amounts of precipitation should be expected than at inland locations. The passage of relatively warm moist air from the open ocean over the cold ice surface can produce relatively heavy precipitation. On the remote summit plateau the predominant air masses are relatively dry. Over the interior of the continent practically all precipitation is in frozen forms such as snow, ice needles, ice crystals, or graupel. Heavy rime and hoarfrost deposits have also been recorded. Toward the ice edge some of the precipitation is in the form of rain. Over open water liquid precipitation predominates.

FIGURE 23-20 shows the percentage of observations with any form of precipitation by black isolines and the percentage of observations with snow by red isolines. For some coastal locations numbers indicate the frequency of days with precipitation (including observations of rain and snow).

1. Region of the continental high

South of the ice limits within the influence of the continental *high*, the synoptic pressure pattern is one of divergent airflow. High altitudes, low temperatures, and steep mountain barriers cause many climatologists to speculate on the possibility of the Antarctic interior being classified as a desert. The polar easterlies associated

with the continental *high* are relatively dry winds by comparison with the maritime westerlies farther north. The total amount of snowfall over many days is often no more than a trace. Rain or drizzle are extremely rare, and snow of a very fine granular type is the usual form. This fine textured dry snow, often driven by high winds, introduces a special problem to all forms of operations inasmuch as it filters into everything not securely closed or packed, such as equipment, supplies, shelters, and clothing.

Records at Little America for 1928, 1930, and 1933 to 1935 also stress the fact that the large number of days with snowfall must not be interpreted as indicating correspondingly large amounts, since in many instances the snow was very light and amounted to only a trace. Mist is also mentioned but described as barely perceptible. Frequent falls of fine ice needles or spicules are recorded and sometimes occurred with perfectly clear skies.

The entire precipitation problem in the Area is complicated by the high percentage of moderate to high winds. Blowing and drifting snow on the ice barriers and on the continent proper often completely overshadows any snow that is actually falling. This feature of the Antarctic seriously affects the trafficability and visibility over these regions. The blowing and drifting may be a shallow surface phenomenon with good visibility and clear sky overhead, or it may be a deep air layer full of blowing snow, crystals, or bunched large flakes, blotting out all means of orientation and lasting uninterrupted for days. Obviously, when blowing and drifting in any amount occur with falling snow it is impossible to measure the resulting accretion with any degree of accuracy. The gages are filled by drifted snow, buried, or blown clean of all snow. The customary method used to measure snow accretion involves a permanently fixed snow stick or pole which does not give any measurement of amounts fallen. It is simply a check on changes in depth from all causes combined, falling, blowing, and drifting. An example of the magnitude and wide range of possibilities of fallen and drifted snow in some sections and accumulation or lack of snow may be gained from expedition records. The Scott polar party of 1912 and others retraced their outward sled trips on their return by following their old sled runner tracks. Snow had been blown away leaving long stretches of raised tracks which had resisted wind erosion due to compression by the heavy sled runners. On other parts of the trail the ridges had held and accumulated snow so that the trail was obliterated. Contrary to this example of snow blowing away is the record of the search party finding the tent of Scott and his companions at

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79°S. The tent had become two-thirds buried by blowing, drifting, and newly fallen snow in the course of 8 months. Other examples of the depths of accumulated snow are shown by the deep coverings over the buildings, depots, and masts of Little America. At the other extreme are those wind-swept areas where some bare ground persists throughout the year.

In 1929 snow measurements made at Little America gave a total of 103.4 inches from January 1 to December 31 with a maximum of 24.2 inches in March, 16.2 inches in June, 11.3 inches in August, and lesser amounts in the remaining months with a minimum of 2.0 inches in October. In 1940 snow accretion measurements were made by using graduated hickory poles and the daily changes, positive or negative, were noted. The net accumulation for 11½ months was 12 inches of snow with the greatest amounts again in March, June, and August.

During the drift of the *Deutschland* in the Weddell Sea (1911-1912) fairly accurate snow gage readings were obtained on the ice, according to the comments by the observers. This drift was notably free of high surface winds, and the usual difficulties with snow gages were rarely experienced. A total of 42.3 inches were recorded between 11 December 1911 and 16 December 1912. The maximum of 10.2 inches occurred in May and the minimum of 0.7 of an inch in October.

2. Region of the westerlies

The portion of the Area under the influence of the westerlies is chiefly the water surrounding Antarctica, and includes the greater portion of the part over which the Antarctic icepack expands and shrinks. To this should be added most of the Palmer Peninsula which projects well into the flow of the westerlies. The southern limit of the westerlies is approximately at 65°S. with a slight dip southward into the Ross and Weddell Seas. The flow of the westerlies follows more or less the outline of the Antarctic continent.

Within the westerlies lie the paths of practically all the cyclonic disturbances affecting the coast of Antarctica including the belt of pack ice. Moisture content is relatively high in the westerlies because of the relatively mild temperatures overlying the oceanic region dominated by this windstream. Much of the precipitation is rain and drizzle and mixtures of rain and snow, with more snow in the colder months. Another form of precipitation often recorded on the Palmer Peninsula and the islands is rime or hoarfrost from supercooled fogs. The rime deposits on the windward side of obstructions may build up to thicknesses of several feet.

Many of the disturbances moving eastward in the westerlies and coming from west of Cape Horn (10), are channelled through Drake Passage south of Cape Horn. They are deflected southward, cross the Palmer Peninsula, and eventually get into the Weddell Sea. Similar, though not quite as marked, is the passage of disturbances from the southern Indian Ocean into the Ross Sea. From the South Atlantic the disturbances skirt the coast of Antarctica from Cape Norvegia (1) to MacKenzie Bay (2). These disturbances raise the precipitation frequencies as shown by the somewhat concentric rings around the entire continent with more marked effects over the two major indentations, the Weddell and Ross Seas (FIGURE 23-20). Observations on and along the coasts of the Palmer Peninsula indicate that precipitation occurs along the fronts accompanying the depressions which travel in the general west to east direction at frequent intervals throughout the year. The records also show wide variations in various parts of the Palmer Peninsula and outlying islands. Only in some cases can precipitation and blowing snow be differentiated.

E. Cloudiness

Cloudiness in this Area is characterized by the following extremes: 1) a relative minimum near 50°S., which is caused by the waning influence of the subtropical highs; 2) a pronounced maximum near the Antarctic front, which is induced by the extensive water surface, the strong easterly circulation, and active cyclonic activity; 3) a primary minimum over Antarctica, which is attributed to the continental polar climate and the associated anticyclones, widespread subsidence, and low humidity; and 4) secondary maximums and minimums along steep mountain ranges and coastlines, which are due to the orographic modification of the air.

All cloud types have been reported in the Area. The cloud types may be generated either within a homogeneous air mass (maritime air of the westerlies or continental air of the easterlies), where they may form as a result of surface heating or atmospheric stratification, or they may develop along the boundary between two contrasting air masses (Antarctic and polar fronts), where they appear in the usual frontal sequence.

In general the height of clouds decreases with increasing latitude. This behavior is reflected in the low cloud levels observed in this region, particularly south of 70°S. Thus it is not at all unusual for cirriform cloudiness, the "high" clouds of warmer latitudes, to be seen at or near ground level in the mountainous interior.

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Over open water most low cloud layers are usually found between 1,000 and 2,000 feet. Around the perimeter of Antarctica, where orographic and frontal clouds are prevalent, as much as 60% to 80% of the cloudiness may remain below 2,000 feet.

Four typical cloud conditions for the Area are presented in a series of 16 charts. FIGURE 23-21 shows the mean total cloud amount for 12 months as well as the percentage frequency of low cloudiness between 6- and 10-tenths for 4 representative months. FIGURES 23-7 through 23-10, representing February, May, August, and November, give the percent observations of two types of sky cover, 0 to 2-tenths and 8- to 10-tenths. On these charts, high frequencies of total cloudiness correspond with large amounts of low cloudiness and an absence of clear skies.

1. Region of the continental high

In the interior of Antarctica, the average cloud amount and the number of overcast days reach a minimum which sharply contrasts with the maximum along the Antarctic front. This minimum cloudiness is induced by the polar *highs* and the associated subsidence and by the low vapor content of the air. However, this pattern is disrupted locally by patches of orographic cloudiness caused by a steep coastline, such as that of Enderby Land (20), and by the extensive mountain ranges of the continent. Downslope flow is reflected by cloud minimums over the Ross Ice Shelf, along the inner periphery of the Weddell Sea, and near the coastlines of Queen Maud Land and Wilkes Land.

Because of the lack of sustained meteorological observations inland, a reliable distribution of clear and cloudy conditions is unavailable. At Little America (7) mostly cloudy and clear skies have been noted on an annual average of 150 and 90 days, respectively.

Cloudiness in the easterlies reaches its seasonal minimum in winter when the long nights and the expansion of the ice field further intensify the polar anticyclones. For instance, Little America has reported as many as 17 clear days in July.

Toward the South Pole, day and night tend to become identified more and more with summer and winter. Consequently, the diurnal variation in cloudiness—maximum in the daytime, minimum at night—slowly blends into the seasonal cycle of summer maximum and winter minimum.

In the easterlies, the cloudiness often assumes the form of stratiform clouds because of the greater atmospheric stability. Low clouds may also be observed on the windward side of mountains and, together with higher forms of cloudiness, may be the harbingers of blizzards. In the Antarctic, mid-

dle cloudiness, which generally assumes the form of altocumulus, is less common than in warmer latitudes.

Cirriform cloudiness in the Antarctic is found at much lower elevations than in middle latitudes and, as a result, may erroneously be grouped with "low" cloudiness. Owing to the ice structure of cirriform clouds, which is demonstrated by the deposition of ice particles and the occasional appearance of ice fog at the surface, the term "low" cloudiness is reserved for stratiform clouds. Cirriform clouds travel rapidly when close to the surface, continuously changing in shape and sometimes forming and dispersing without visible reason.

High cloudiness in this region appears in the following order of occurrence of each type: cirrus, the most common; cirrostratus; cirrocumulus, which, even though less frequent than the other types, is still observed with greater frequency than in lower latitudes.

Perhaps as a result of the lesser amount of obscuring low cloudiness, cirriform clouds are reported more often in the region of easterlies than north of the Antarctic front. These clouds are often the forerunners of inclement weather, such as a blizzard moving from the interior or a cyclonic disturbance straying from the westerlies.

High cirriform cloudiness is frequently connected with the upper-air convergence over Antarctica and the associated cyclonic inflow of northerly air aloft. These upper clouds usually drift from the northwest and west, thus assuming a direction nearly opposite to the surface flow.

Convective cloudiness is uncommon in the zone of easterlies south of the ice limit. When convective cloudiness occurs north of the ice limit, it is associated with fresh outbreaks of Antarctic air. The observing of low convective clouds can be of use to ice breaker navigation in estimating the location of leads and open water areas.

Most clouds observed in the Antarctic are located in the troposphere. Cirruslike formations, however, are observed in the stratosphere. Commonly known as mother-of-pearl clouds, they may occasionally cover a large portion of the sky with a flimsy film of cloudiness reflecting the last rays of the sun. Because of their unusually high elevation in the stratosphere these clouds may be observed only after the lower atmosphere has become immersed in darkness.

Flying may be dangerous on the windward side of islands and inland ranges because of the orographic cloudiness. Moreover, aircraft are faced with the ever-present danger of icing when in contact with the supercooled droplets of middle and low clouds.

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At the surface the dazzling daytime combination of snow, ice, and clear skies usually causes great discomfort to the eyes unless dark glasses are worn.

2. Region of the westerlies

The cloudiness in this region is characterized by a wide band of thick low cloudiness whose maximum is located along the Antarctic front. However, the uniformity of this belt is interrupted by orographic maximums on the eastern shores of indentations and along the west coast of South America, and by extensions of the cloud maximum into the Ross and Weddell Seas.

Concurrent with the mean cloud pattern, the frequency of cloudy skies increases south of 50°S. and that of clear skies decreases. Thus, cloudy conditions annually prevail on 160 days in South Georgia, 188 in the South Orkney Islands, and 240 near Deception Island (9). In any one year the maximum may be greater than 260 days. Locally, overcast skies have been reported in the Ross Sea on 22 days of a summer month.

Along the northern fringe of the Area, as the subtropical *highs* reach their southernmost extent in summer, cloudless conditions may prevail on as many as 50 days each year. A local minimum, attributed to the "drying out" effect of the Andes, is

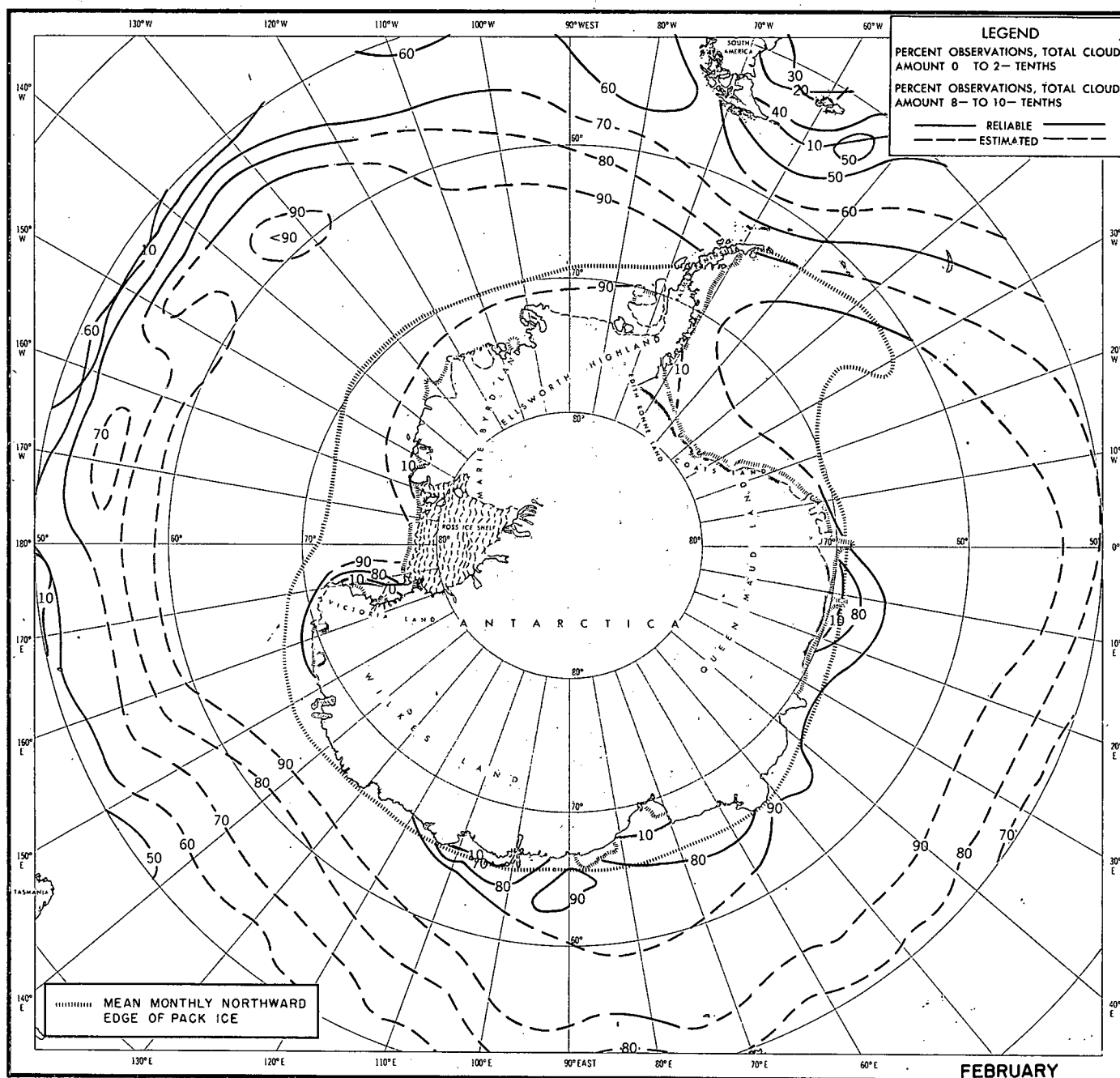


FIGURE 23-7. PERCENTAGE OF OBSERVATIONS WITH TOTAL CLOUD AMOUNT 0 TO 2-TENTHS AND 8- TO 10-TENTHS, FEBRUARY

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centered along the Argentine coast. The near absence of clear days per year in the westerlies is typified by the following observations: Falkland Islands, 18; South Georgia, 15; South Orkney Islands, 11; and South Shetland Islands, 4. Near the Antarctic air mass, however, a sudden improvement to clear conditions may result from the onset of an offshore wind.

Because of the greater air mass contrast and the consequent increased cyclonic activity mean cloudiness reaches its annual maximum in winter. However, the northward migration of the zone of westerlies in winter conceals much of this seasonal increase. With the southward retreat of ice in

summer and the simultaneous invasion of easterly winds the densest part of the cloud blanket, although at a minimum in this season, may penetrate as far south as the coastline.

Between 50°S. and the Antarctic front, the diurnal change in the cloudiness usually follows a cycle whose regularity depends on the length of day and night. Nevertheless, a cloud minimum is usually observed at night, some time around midnight; a maximum occurs in the morning hours, shortly before noon.

The low cloudiness, which forms a large percentage of the total cloudiness, particularly in winter, is prevalent everywhere in the westerlies. Layers

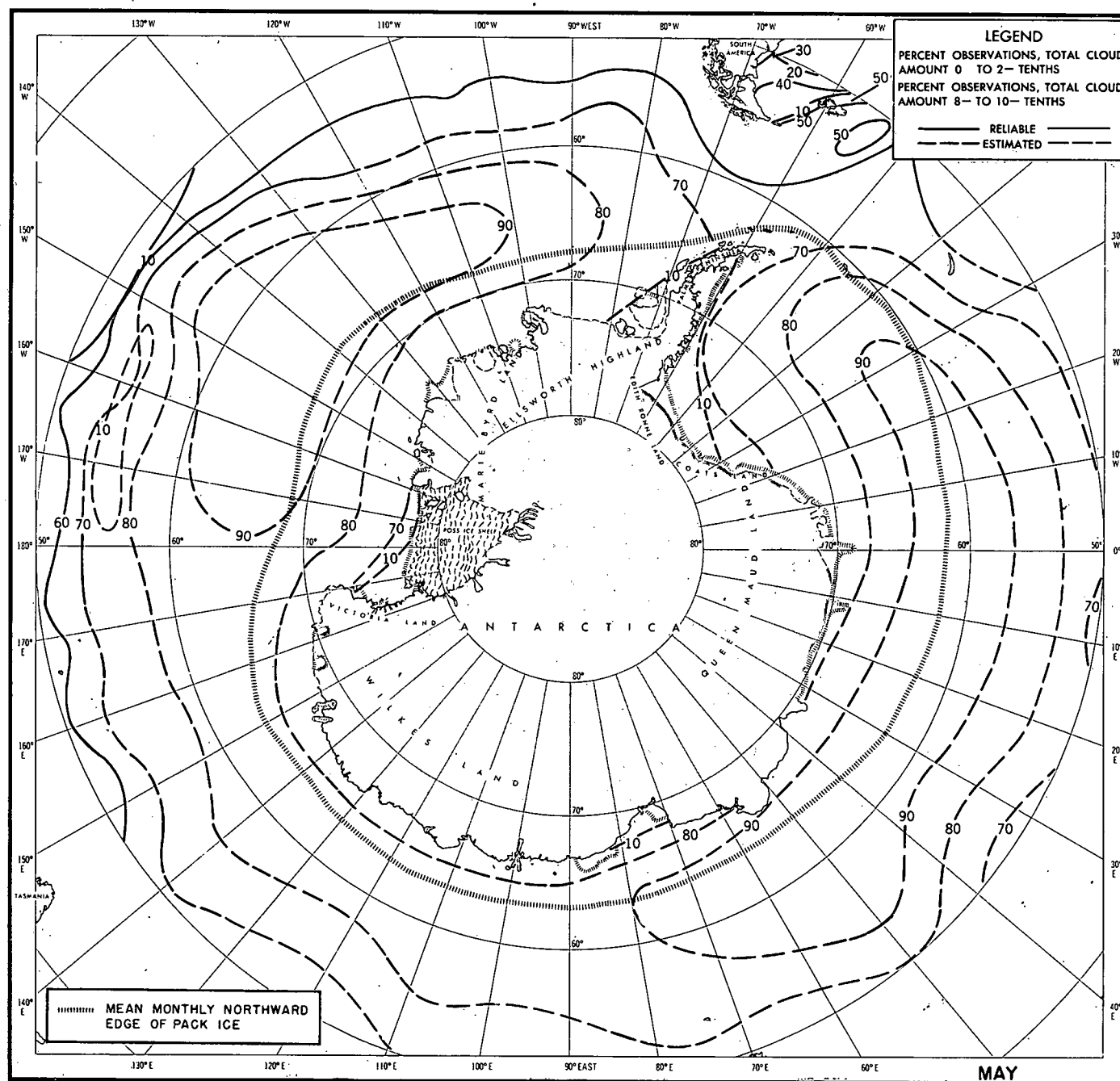


FIGURE 23-8. PERCENTAGE OF OBSERVATIONS WITH TOTAL CLOUD AMOUNT 0 TO 2-TENTHS AND 8- TO 10-TENTHS, MAY

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of stratus and stratocumulus clouds are the most common form encountered throughout the region, the latter type having been reported in up to 90% of the cloud observations near the Antarctic front.

Near 50°S., the mean height of stratiform clouds varies from about 2,500 feet for stratus to about 6,000 feet for stratocumulus. They may be found at much lower altitudes near the southern fringe of the westerlies. Thus, at Little America, stratus layers average about 900 feet and stratocumulus about 1,500 feet.

Middle clouds, generally found in this Area as altocumulus first and altostratus second, are not as widely reported as low cloudiness, perhaps as a

result of the obscuring effect of the underlying layer. However, wherever downslope motion dissipates the stratiform cloudiness, as along the Antarctic coast and near the Palmer Peninsula, middle cloudiness becomes dominant, often being reported as altocumulus lenticularis. The mean lower level of middle clouds slopes downward from a height of about 13,000 feet along the northern boundary of the Area to about 3,000 feet near the Antarctic front.

High clouds, which are usually associated with frontal activity, are about equally divided between cirrus and cirrostratus. Although more common than in middle latitudes, cirrocumulus clouds

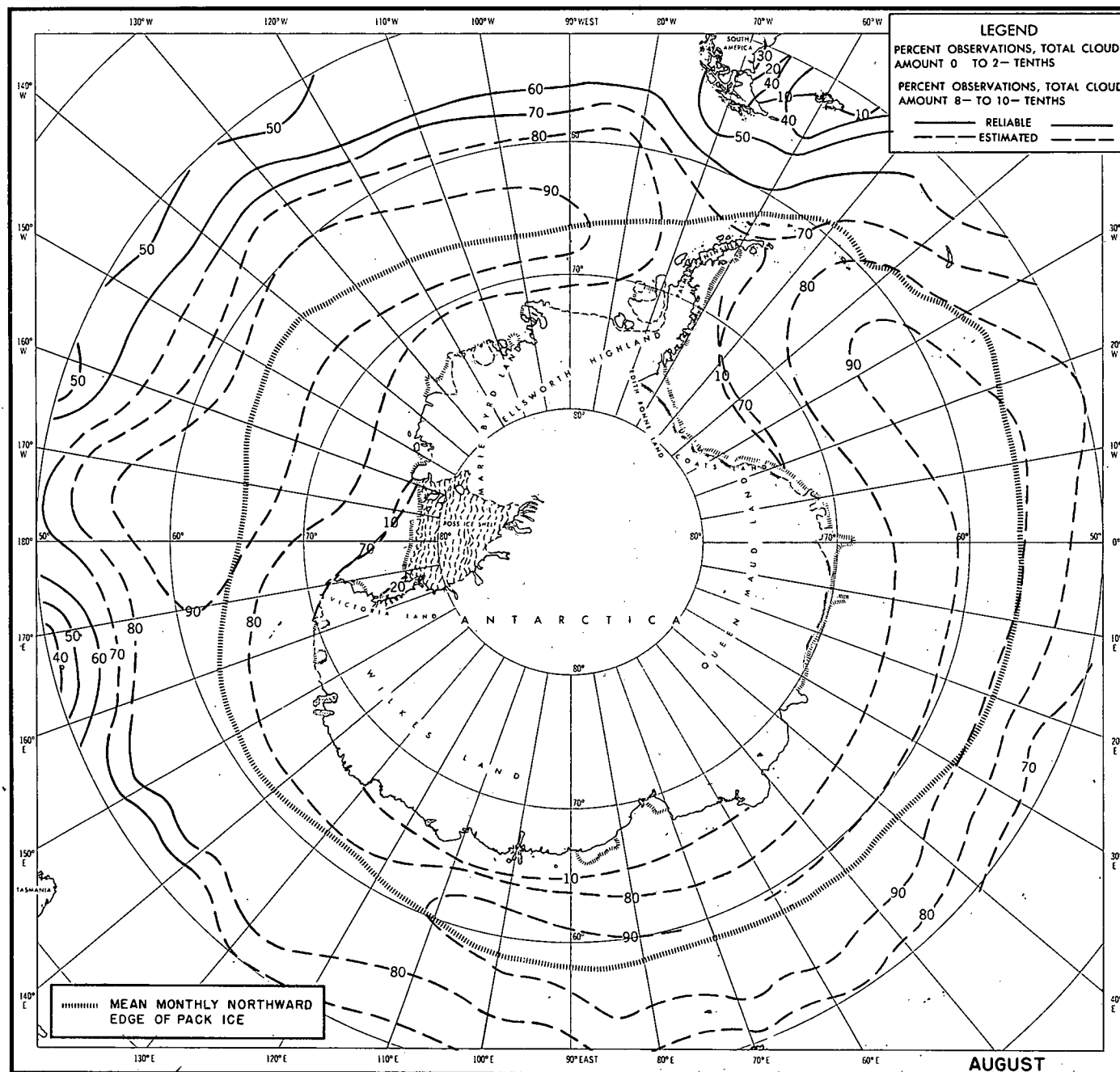


FIGURE 23-9. PERCENTAGE OF OBSERVATIONS WITH TOTAL CLOUD AMOUNT 0 TO 2-TENTHS AND 8- TO 10-TENTHS, AUGUST

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rarely form more than 5% of the high cloudiness. Again because of the prevalent low overcast, these clouds may not be reported as often as they occur.

Near 50°S., cirriform clouds have average heights of 21,000 to 29,000 feet in winter and 23,000 to 30,000 feet in summer. Along the southern boundary of the region, where they may be found as high as 20,000 feet, high clouds frequently appear at a level much below 10,000 feet.

Convective clouds, and more particularly cumulonimbus clouds, are the least commonly observed cloud family in the region of the westerlies. From a maximum frequency along the northern fringe, especially along the east coast of South America,

cumuliform cloudiness becomes progressively sparser with increasing latitude. Cumulonimbus clouds, which are uncommon north of 65°S. except near the Strait of Magellan (21), nearly disappear south of this latitude. Cumulus congestus may be observed for several degrees more but soon become scarce also. Cumulus clouds, in turn, become less likely; however, they are never absent from the southernmost part of the westerlies, except in winter. Over the Weddell and Ross Seas convective cloudiness reaches an absolute minimum, normally accounting for less than 1% of the observations in summer. Cold outbreaks over warmer water often

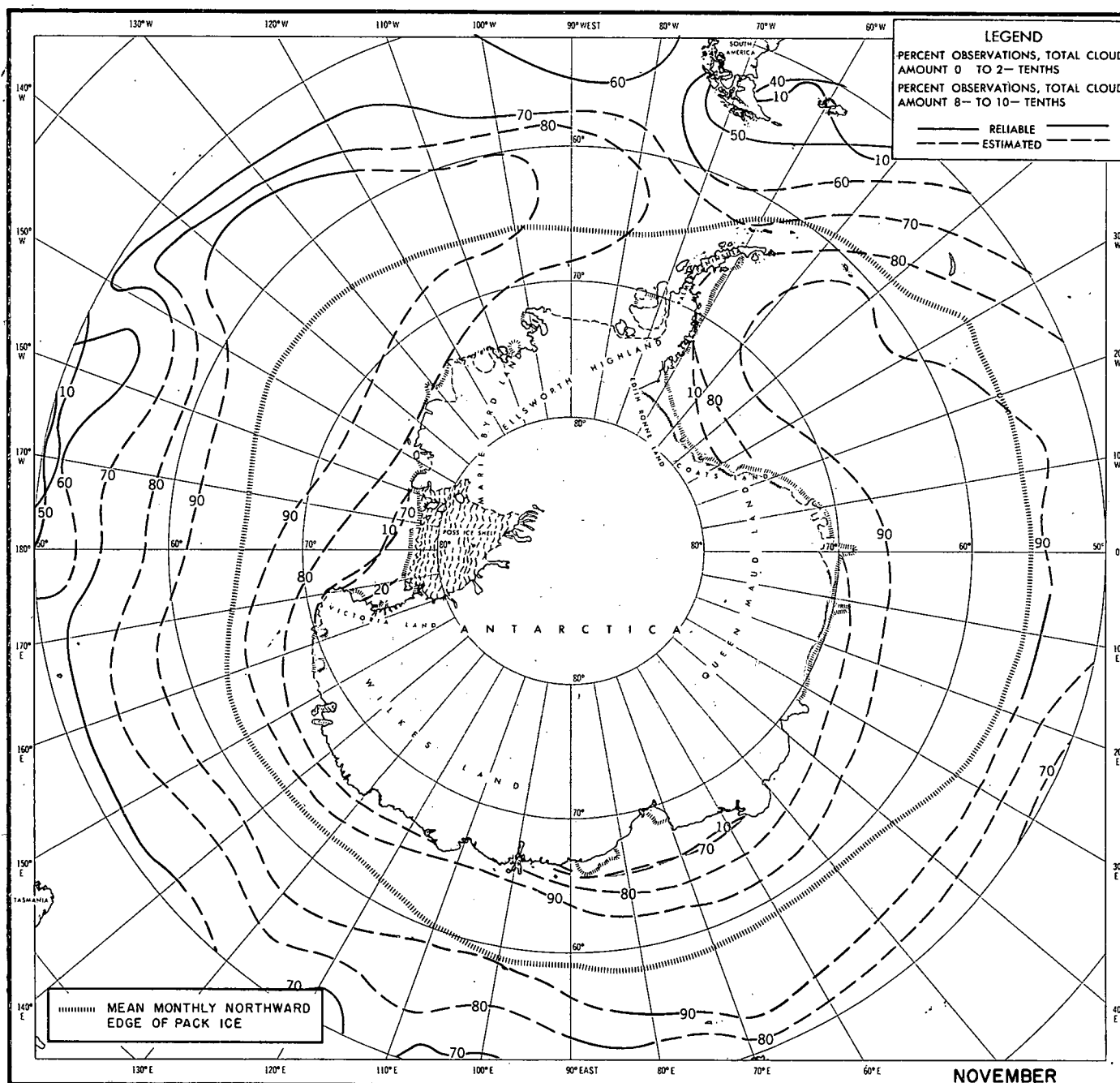


FIGURE 23-10. PERCENTAGE OF OBSERVATIONS WITH TOTAL CLOUD AMOUNT 0 TO 2-TENTHS AND 8- TO 10-TENTHS, NOVEMBER

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create instability cloudiness in the westerlies, especially in summer.

Because of the prevalence of thick low cloudiness in the westerlies, aircraft may be endangered, particularly near islands and coastal regions where steep rises may be completely invisible to approaching aircraft. Land personnel may at times feel depressed as a result of the uniform gray overcast that may linger on for several days near the Antarctic front.

F. Visibility

Reduced visibility is frequently associated with storms in this Area. In the frontal zone precipitation may be accompanied by fog which often persists in the area of precipitation. Over the continental region blowing snow is a frequent obstruction which sometimes extends over the coastal waters. Other restrictions occur with various frequencies depending on the particular locality. Sea fog forms where moist winds blow from warmer to colder water, especially in regions of a strong temperature gradient. Drizzle often occurs. Steam fog, also called sea smoke, occurs over coastal waters whenever very cold air blows outward over the warmer water. Advection fogs form in circulations having a trajectory partly over the water and partly over the pack ice. Radiation fog occurs infrequently. Ice crystals, formed by vapor condensing directly to ice, rarely become thick enough to restrict visibility appreciably. Due to the absence of sources of smoke or dust, haze is not encountered.

Visibilities restricted to less than 5 miles and to less than $\frac{1}{2}$ mile are shown in Figure 23-22. Days with fog are shown numerically at several locations. Actual visibility restriction by percentage frequency may differ from the frequency by days, since fogs may be frequently of short duration or other obstructions may occur.

1. Region of the continental high

In general, the continental *high* extends to about the northern edge of the icepack. In the interior storm frequencies are low and atmospheric moisture is at a minimum. The slight precipitation which occurs is in the form of dry powdery snow or ice needles. This powdery snow cover is ideal for blowing snow which constitutes the chief obstruction to visibility. After several days of hard steady blowing the snow becomes packed in ridges. Packing reduces the amount of snow borne aloft. The severity of restriction to visibility depends on the strength of the wind and on the amount and recency of the snowfall. A 20-knot wind over a heavy, recent, dry snowfall can raise blowing snow to a height of several feet and a 40-knot gale can raise blowing snow as high as 50 feet. In blowing

snow visibility may be reduced to less than 100 yards. When the snow is wind packed after a blow of several days, even a 40- to 60-knot gale can scarcely raise blowing snow more than a few feet above the surface. In several recorded instances aerial missions were completed in drifting snow driven by gale winds several days old. Drifts occasionally reaching a height of 6 feet were a nuisance but not a hazard. Near the summer solstice (22 December) even the slight thawing of the snow surface greatly reduces the available snow for drifting.

Anywhere over snow or ice a dangerous condition known as "white-out" may occur. Although actual visibility may be good, depth perception is greatly reduced; white objects blend with the white background so that they are not perceived. A thick overcast hides the sun and blends with the snow surface making the horizon indistinguishable. The heavy cloud cover and reflecting snow surface render the light so diffuse that contrasts in shading disappear. Instances of aircraft crashing into glaciers or into snow covered mountains have occurred with "good" visibilities. Most dangerous conditions arise with low ceilings, solid overcasts, and actual visibilities reduced by mist. Less serious reductions of depth perception occur with high thin sky cover.

At the northern limit of the continental *high*, near the edge of the pack ice, there is a zone of interaction between the continental *high* and the westerlies. Here cyclones form connecting wheels of circulation between the easterlies and the prevailing westerlies to the north. This is a region of frequent storms with resulting poor visibility in most longitudes. In addition to the frontal and precipitation fogs often present in storms, mists sometimes are observed which reduce visibility to 5 miles or less. Although snow is the usual form of precipitation, drizzle can occur. These mists and occurrences of drizzle are found in as widely separated places as along the coasts of the Ross Sea and Palmer Peninsula. Advection fogs occur in moist air when the circulation of a *low* moves over the pack ice. With a short but sufficient trajectory over the ice the air is cooled to the condensation point and becomes laden with fog. On rare occasions radiation fogs form in protected areas. These are usually composed of super-cooled water droplets, but observations of ice fogs at Marguerite Bay (8) were reported with temperatures below -25° F. Steam fog or sea smoke is produced when the cold continental air blows over coastal waters. The vapor pressure of the water surface must be about 5 millibars greater than the vapor pressure of the air for steaming to occur. Steam fog is not generally more than 50 to 100 feet deep. Blowing snow may also extend over the coastal waters.

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In regions of pronounced outflow such as from Davies Bay (22), eastward to Cape Adare (5) visibility is good in coastal waters except for steam fog and blowing snow close to shore. Over the land or ice surface the chief obstruction to visibility is blowing snow which occurs with great steadiness because of the constant high winds.

2. Region of the westerlies

North of the pack ice in the belt of westerlies frontal fogs and sea fogs are frequent obstructions to visibility. Sea surface temperature gradients coupled with moist winds blowing toward the colder water produce sea fogs. Both storm frequencies and sea surface temperature gradients decrease northward, except at the Antarctic Convergence where there is a temperature discontinuity. The Antarctic Convergence lies near 50°S. latitude over much of its extent. Through Drake Passage, however, it lies midway between Cape Horn and the Palmer Peninsula. West of South Georgia there is a pronounced hook in the convergence where it is oriented north and south for several degrees of latitude. Here westerly winds blow perpendicular to the isotherms accounting for some fog in the area.

A typical sequence of visibilities during a storm passage has been described by the observing ship which left Scott Island (6) at 1200 GMT on December 17th bound for the Shackleton Ice Shelf (3). The so-called Balleny Islands high-pressure ridge was passed at about 1100 GMT on the 18th. A shield of upper clouds began to appear and the pressure began to fall steadily. At about 2200 GMT on the 18th a frontal passage occurred with the wind shifting rapidly from northeast to west-northwest and the velocity increasing from 20 to 30 knots. Visibility was greatly reduced by drizzle and fog. This condition lasted several hours. During this time the pressure first rose for a short time, became steady for several hours, and then unsteady and falling. At this time the drizzle and fog ceased with visibility becoming good. The improved visibility lasted for several hours, then the wind shifted to northwest, and visibility lowered in light to moderate fog. This fog persisted until 0730 GMT on the 19th when a second frontal passage occurred, this time with skies clearing and visibility becoming good. Good weather lasted the next 2 days. The first front (in which frontal and post frontal fog and drizzle occurred) was an upper cold front. The second front (with prefrontal fog) was an occlusion.

The northern part of the region experiences generally good visibility, frequencies of visibility less than 5 miles being generally less than 40%.

G. Special weather phenomena

1. Extratropical cyclones

The marine portion of this Area is affected by frequent and intense extratropical cyclones. In the inland portion of the Antarctic continent such storms are uncommon. The seasonal frequency distribution and predominant paths of extratropical cyclone centers for the Area are presented in FIGURES 23-11 through 23-14.

Most *lows* affecting the Area form north of 70°S.; they develop along the polar front, in convergence regions east of continents, and in the semipermanent, elongated low-pressure zone surrounding the Antarctic continent. *Lows* forming along the polar front move southeastward toward the Antarctic continent. As these lows come under the influence of the westerlies, they frequently circulate the continent from west to east. Most *lows* moving into the Area are occluded or occlude soon after entering. The occlusions of these *lows* may become diffuse in the Ross and Weddell Seas where the semipermanent low-pressure belt is relatively pronounced. These pronounced low-pressure zones are sometimes known as the "graveyards" of the migratory *lows*.

Many of the migratory *lows* that do move directly into the Ross and Weddell Seas generally deepen and intensify the circulation in these regions even though the fronts may be poorly defined. Frequently new *lows* form at the base of the occlusions and continue to move eastward. Cyclogenesis along either the Antarctic or polar fronts is most pronounced west of the Ross and Weddell Seas regions where frequent outbreaks of cold continental air steepen the horizontal temperature gradients. The resulting air mass discontinuities are further marked by the differences of the moisture content between the continental and maritime regions. These air mass differences are also relatively pronounced in the Ross and Weddell Seas regions where the coastline is sharply indented.

The main seasonal changes affecting the frequency and intensity of *lows* in this Area are brought about by the heating and cooling of the Antarctic continent. In winter as the continent cools, the northern edge of the pack ice moves northward. The relatively low-pressure belt surrounding the continent closely approximates this northward movement. When the northern edge of the pack ice reaches its northernmost position (generally during the period September through October), the difference between the continental air and maritime air is greatest, resulting in the maximum intensity and frequency of *lows* influencing the Area.

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The *lows* of this Area are characteristically similar to those of the Northern Hemisphere, the only great difference being that the winds blow clockwise toward the center instead of counterclockwise as in the Northern Hemisphere. Also the speed of advance of *lows* seems to be more constant and the paths followed are not so erratic as those in the Northern Hemisphere. This condition is brought about by the more constant high pressure over the Antarctic continent and in the subtropical *highs* over the ocean to the north of the Area. The movement of *lows* is quite rapid, averaging 26 knots in summer and about 39 knots in winter. The vertical structure of the *lows* is very similar

to those of the Northern Hemisphere. In the Southern Hemisphere, however, cloud tops are generally lower than those found under similar synoptic conditions in the Northern Hemisphere.

In the Southern Hemisphere the air mass discontinuity across frontal zones is diminished by the decrease in meridional air transport, which results from the rapid modification of the cold surface layers of polar outbreaks by the relatively warm water masses. Cyclone waves forming along trailing cold fronts have a tendency to migrate from the east coasts of middle latitude continental regions toward the semipermanent *low* regions of the Weddell and Ross Seas. Under these condi-

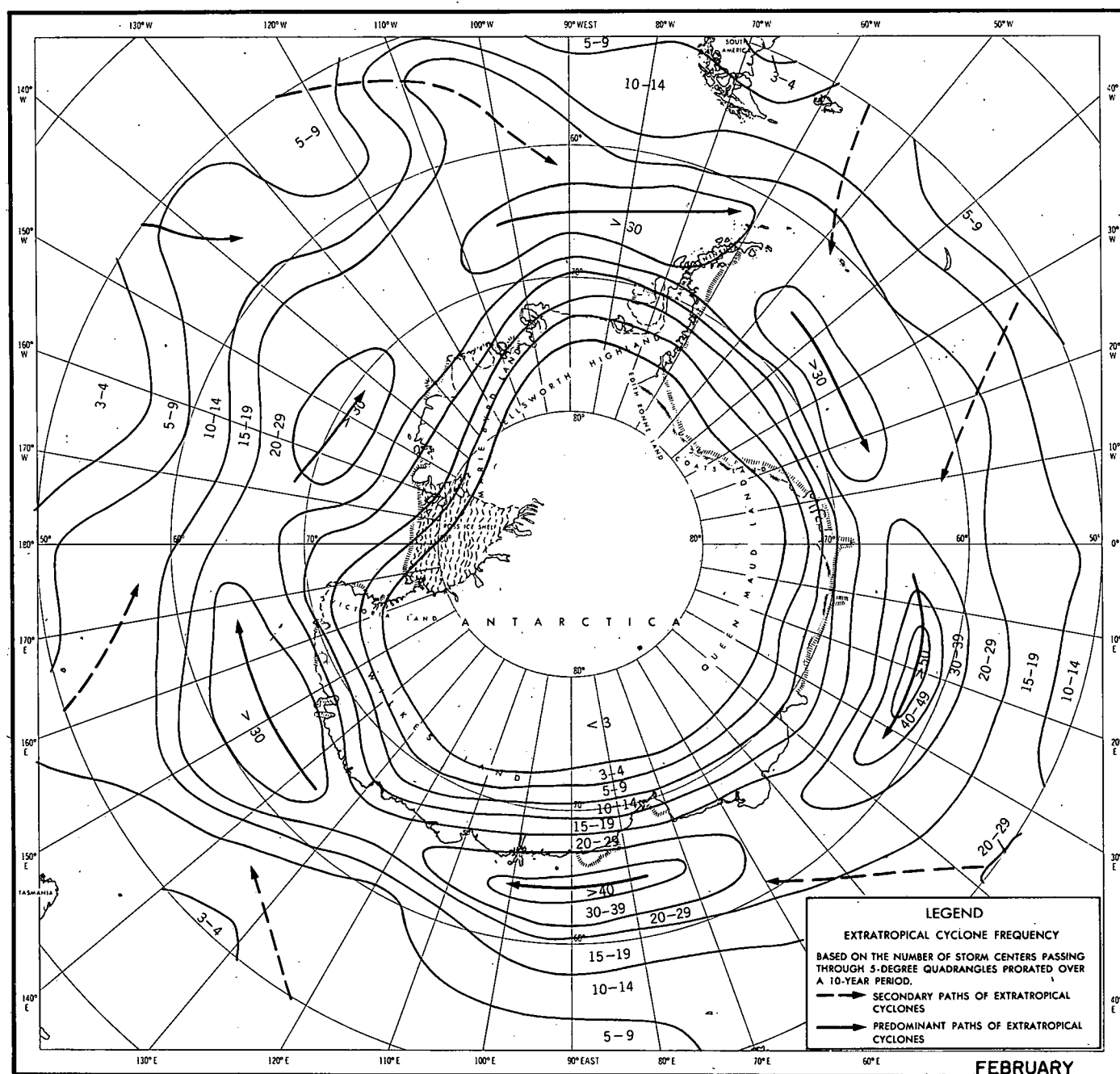


FIGURE 23-11. FREQUENCY AND PATHS OF EXTRATROPICAL CYCLONES, FEBRUARY

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tions "families" of these cyclone waves tend to move around the southern periphery of subtropical *highs* because of the blocking action. As a result the charts indicate a higher frequency of *lows* in these regions than in the central oceanic regions. Intense *lows* moving along the outer boundary of the Antarctic continent generally influence shore stations to the south first with increasing cloudiness moving in from a westerly direction followed by an increase in precipitation and wind force. The precipitation and wind increase until the center of the *low* passes the station. Even after the precipitation ceases, the wind generally holds steady causing blizzard conditions of

drifting snow and extreme cold, which may last from a few hours to several days before abating. Winds in blizzards associated with the passage of *lows* to the north of a station usually begin to blow from the southeast and then back through south to southwest. When a weak *low* influences a station, the associated weather pattern may cover a large area, and there may be several days with overcast skies, continuous light precipitation, and light winds.

In this Area the relationship between barometric fluctuations of pressure and storms is not as marked as in lower latitudes. Heavy gales have been experienced with little variation in the pres-

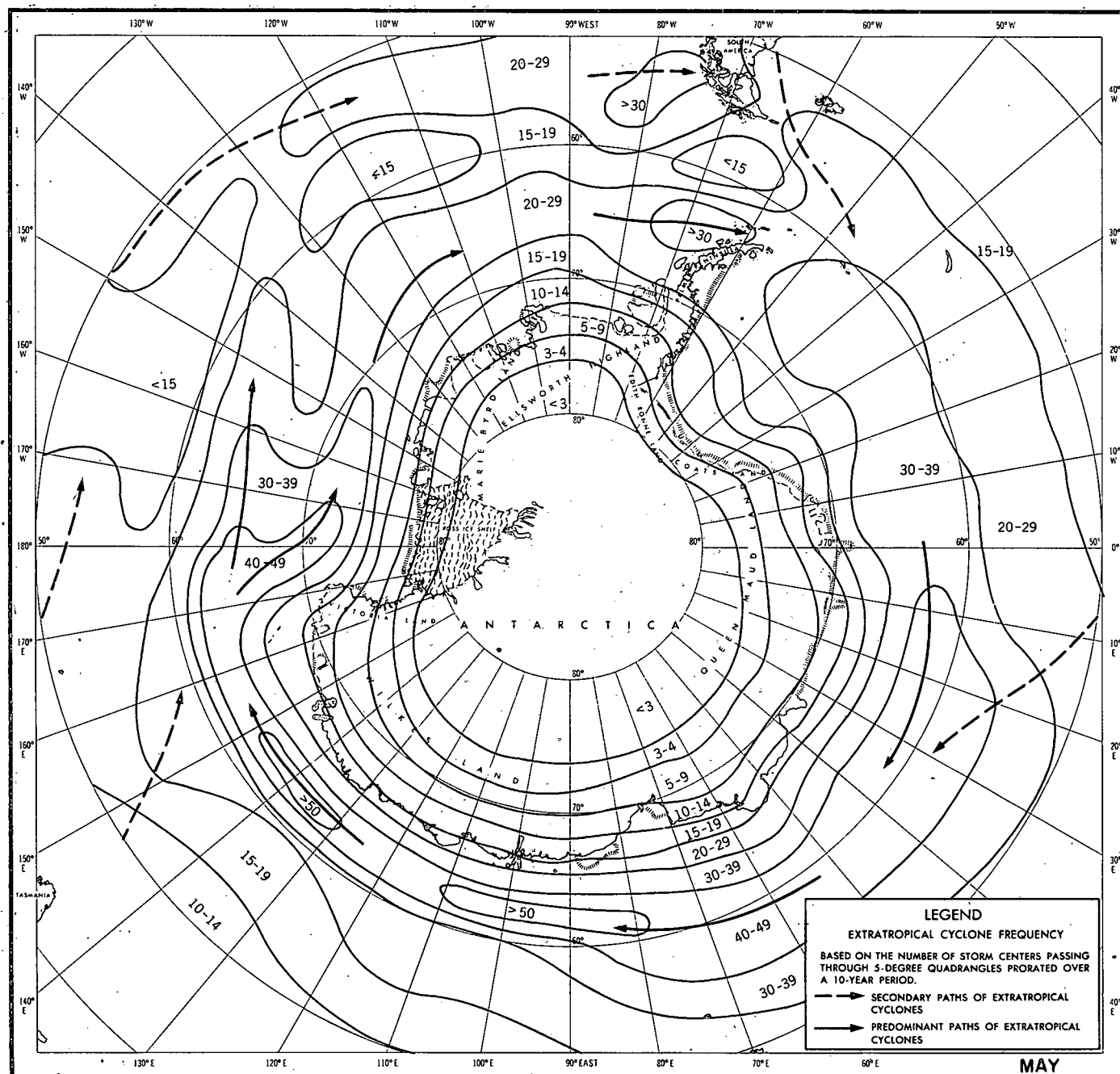


FIGURE 23-12. FREQUENCY AND PATHS OF EXTRATROPICAL CYCLONES, MAY

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sure gradient, while considerable variation in the pressure gradient may be experienced without any appreciable change in the wind force.

Visual signs are frequently helpful where the lack of data is a forecasting handicap. In general, most storms with widespread precipitation migrate from the west and northwest. With the passage of the *lows* to the north, blizzards with winds generally blowing from the southern quadrants are established along the coast of Antarctica. The approach of a migratory *low* is indicated by falling pressure accompanied by winds from an easterly quadrant. When clear anticyclonic weather is observed, the barometric pressure tendency is not

always the first indication of an approaching *low*; cirrus or often a deck of altocumulus rising on the western horizon 100 to 200 miles in distance could be the first indication. Several hours later the first pressure waves of the *low*'s approach are manifested by the falling barograph. Gradually mist fills the atmosphere reducing visibility from unlimited to a few miles. About 8 hours after the first appearance of cirrus, a stratus deck begins to form becoming overcast within a few hours. The passage of a migratory *low* is indicated by rising pressure and winds from a westerly quadrant. Storms have a tendency to occur every 3 to 5 days. Usually, extensive precipitation is associated with

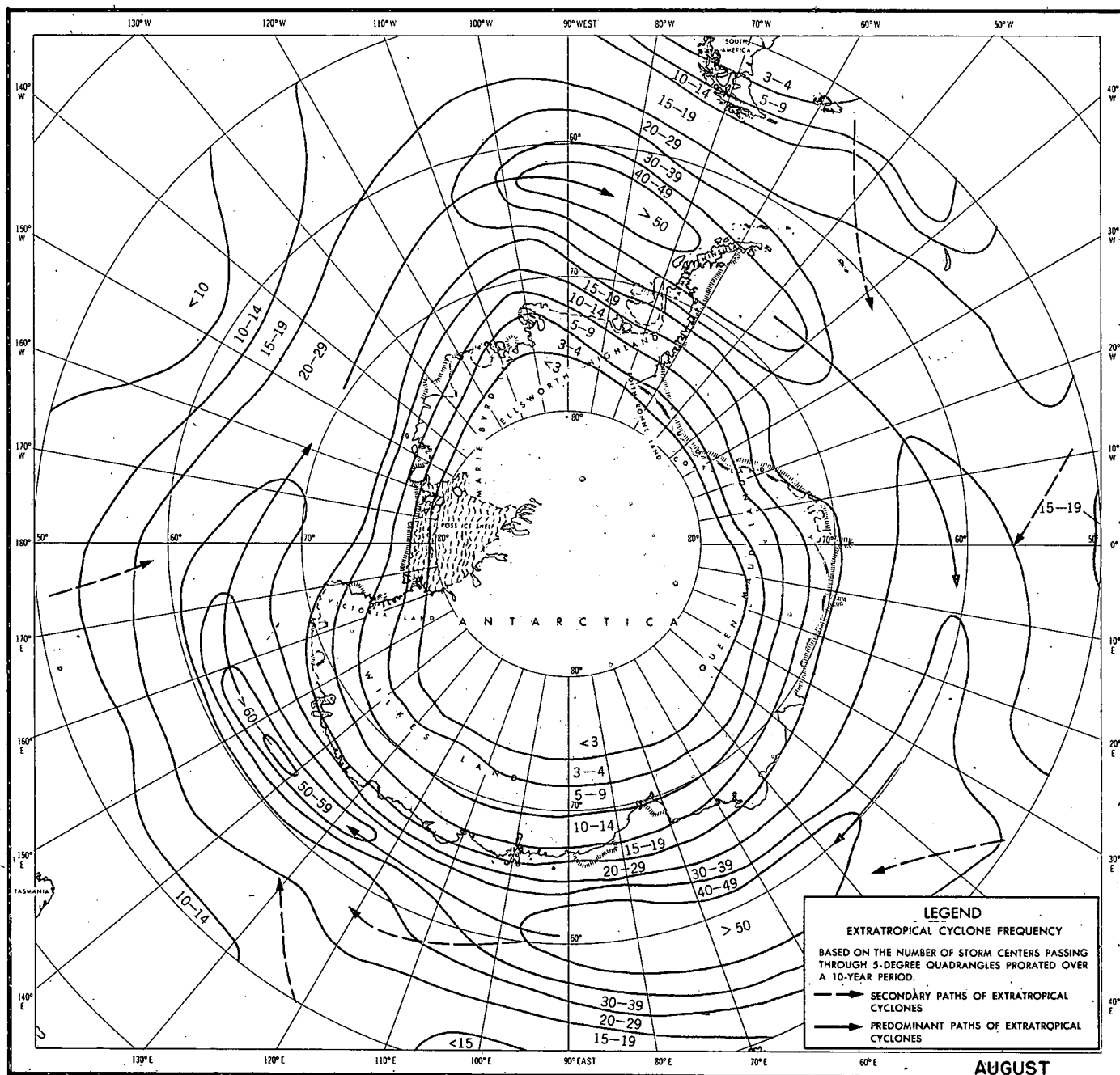


FIGURE 23-13. FREQUENCY AND PATHS OF EXTRATROPICAL CYCLONES, AUGUST

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moderately deep *lows* (over a 20-mb. fall). Humidity and the tracks of migratory pressure systems are also important considerations. The high frequency of fast moving *lows* in the Area results in great variations in the day-to-day weather throughout the marine and coastal regions.

2. Thunderstorms

Conditions favorable to thunderstorm activity, such as unstable warm moist air and an appreciable cloud thickness between the cloud base (condensation level) and icing level, rarely occur in this Area. The few thunderstorms, lightning flashes, or distant lightning or thunder observed indicate

an increase in frequency from Antarctica toward lower latitudes. Frontal type thunderstorms may develop from time to time in intense cyclonic disturbances having well-defined frontal discontinuities which move east or southeast in the westerlies. Such storms have been observed on the Palmer Peninsula and over the island groups. Air mass type thunderstorms are relatively rare.

Expedition reports reveal the trend of an increase in thunderstorm frequency toward the north: 1) At latitude 66°02'S. and longitude 89°38'E., the site of the *Gauss* expedition of 1902, no thunderstorms, lightning, or thunder were recorded in 1 year of observations. 2) At Laurie Is-

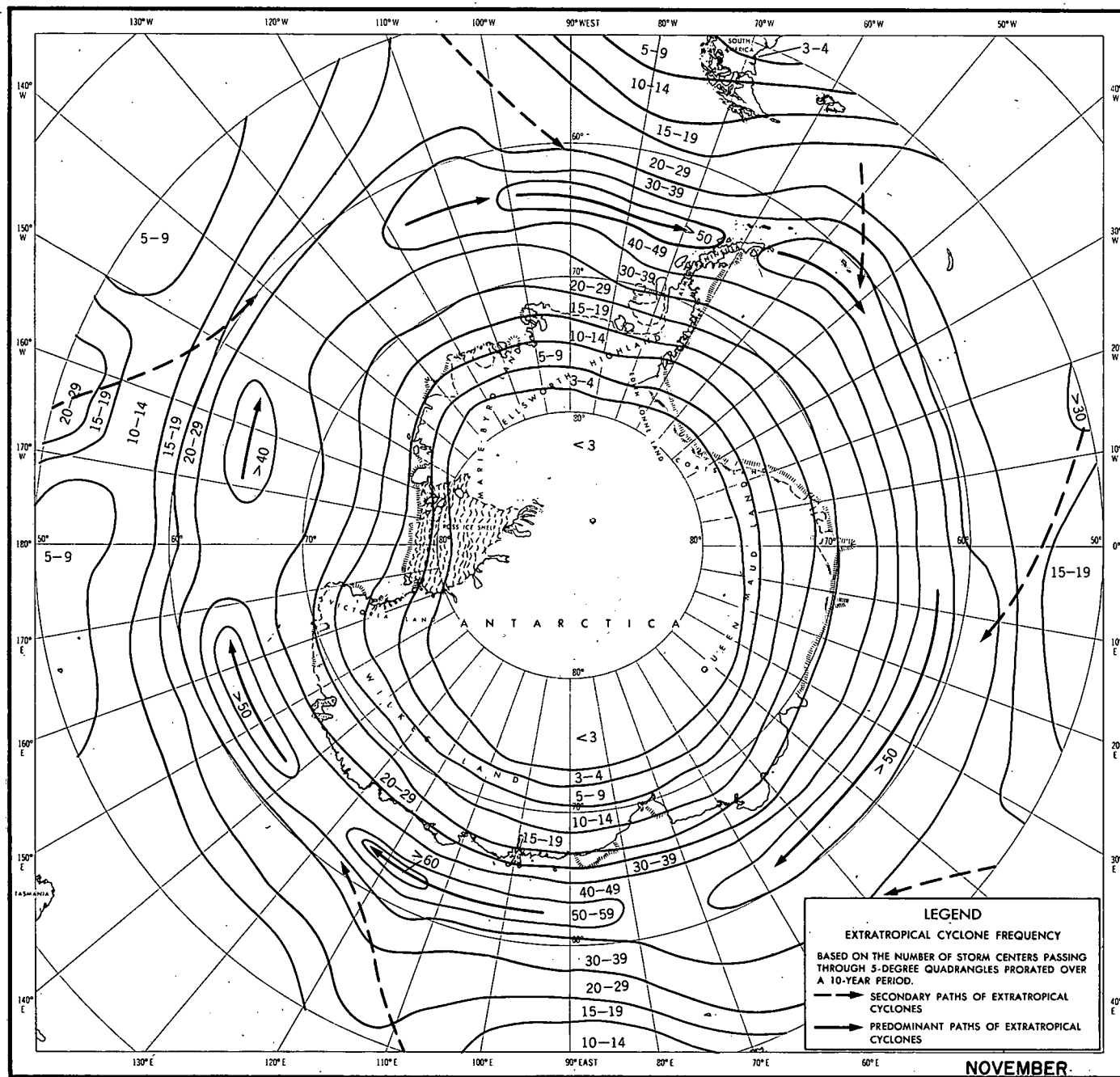


FIGURE 23-14. FREQUENCY AND PATHS OF EXTRATROPICAL CYCLONES, NOVEMBER

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land (60°45'S., 44°35'W.) in the South Orkney Islands, 2 days on which thunderstorms occurred and 3 days on which distant lightning was seen were recorded during the period from 1903 to 1910. 3) At Macquarie Island (54°37'S., 158°54'E.) a lightning flash was observed in May 1931 and other discharges were observed in August of the same year. In March 1915 a severe thunderstorm was seen approaching the station of the Australian Antarctic Expedition. Further details on this storm are lacking. 4) In South Georgia (54°15'S., 36°45'W.), thunder was heard 3 times in the 7-year period, 1944 through 1950. 5) Port Stanley (51°42'S., 57°51'W.) in the Falkland Islands recorded 21 occurrences of thunder in the same 7-year period, 1944 through 1950. At Cape Pembroke (51°00'S., 57°00'W.), the *Scotia* recorded 3 thunderstorms in 1903 and 1904.

3. Waterspouts

There are two types of waterspouts, the tornado type having violent, destructive winds and the fair-weather type resembling dust devils over land. Tornado-type spouts occur in extremely unstable air and are usually associated with cold fronts. Conditions favorable for the formation of waterspouts are also favorable for the formation of thunderstorms. Fair-weather spouts are associated with mild convective activity.

Neither type has been reported from available observations taken in Antarctic waters. Since the density of observations is considerably less in these regions than in other parts of the world, the possibility of waterspouts is not excluded. However, if any occur the frequency is very low. The possibility is greatest near the northern extremity of the Area, especially in the vicinity of the Falkland Islands where thunderstorm frequencies are highest.

Whirlwinds of snow have been reported on the ice slope of Adélie Coast (4) about a mile inland and several hundred feet above mean sea level. It is possible that these may occasionally reach the coastal waters and become fair-weather spouts, or they may occur in regions having steep slopes adjacent to open water.

4. Optical phenomena

Optical phenomena are common in the region south of 50°S. but their frequency reaches a maximum in Antarctica, where they help to dispel the monotonous combination of ice and snow. These phenomena, whose appearance ranges from intricate geometrical patterns to colorful electrical displays, are caused either by the alteration of the light from the moon and the sun or by atmospheric electricity. Depending on the type, size, shape, and position of the intervening particles, the in-

coming light may be refracted, diffracted, or reflected, or it may undergo two or more of these processes simultaneously.

Refraction through the clear atmosphere occurs with favorable temperature lapse rates. Whenever the cold surface air is capped by a pronounced temperature inversion in the Antarctic, the outline of distant objects, usually icebergs and islets, is altered markedly by refraction (looming, towering, superior mirages). When these objects seem to be lifted above their true position, thus appearing closer to the observer, looming is said to occur. If, in addition, there is vertical stretching of the image the refraction phenomenon is known as towering. Finally, objects that appear as though they are reflected from the sky, sometimes as inverted images topped by their erect counterpart, are observed as superior mirages.

Near the ice limit looming and superior mirages frequently combine to raise the apparent position of icebergs and islets several degrees above their true position. The impression of a greatly expanded ice field and of much reduced horizontal distances is created, particularly when great numbers of otherwise invisible bergs are lifted into view as the stretched upper image of superior mirages. Some of these appear as lofty pinnacles which are commonly known as *Fata Morgana*. There may occasionally be two horizons and two iceberg fields, the ghostly bluish floes being associated with the mirage horizon.

On clear days shortly after sunset or before sunrise the green light is sometimes refracted from the sun's spectrum. This refractive phenomenon, which may be witnessed at all latitudes, is known as the "green flash."

In the Antarctic other varieties of refractive phenomena, several of which may appear simultaneously, are associated with the abundance of ice particles (cirriform cloudiness, falling ice crystals, ice fog, drifting snow). These phenomena are faintly colored, with red being closest to the light source. They include rings around the sun (22- and 46-degree halos), arcs open toward the sun (Parry-arcs, Lowitz-arcs, upper tangent arcs), arcs that open away from the sun (circumzenithal arcs, infralateral tangent arcs, lower tangent arcs, circumhorizontal arcs, supralateral tangent arcs), mock images (parhelia), and various geometrical figures located in remote parts of the sky with reference to the sun (anethelia, anethelic arcs, paranethelia).

Solar halos may be observed several times during any one month but their frequency decreases with the length of day. Lunar halos are less common.

Fogbows that are caused either by ice or water particles are seen when the observer is looking away from the sun and are sometimes surrounded

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by supernumeraries. The fogbow, although occasionally brilliantly colored, is normally visible as a broad white band with faintly tinted borders.

Diffractional phenomena are often similar to those caused by refraction except for a reversal in the spectrum colors, red being away from the source of light. Several widely observed phenomena in the Antarctic are due to diffraction. These include the Brocken bow, or glory, which appears on clouds and fog banks as colored rings around the shadow of a person's head; the solar and lunar corona, which resemble the halo and are observed only through high cloudiness but whose size varies inversely with that of the particles; and solar and lunar iridescence, which may be seen away from the sun but in reverse order to direct iridescence.

Sun pillars and parhelic circles are due to the reflection of sunlight from flat crystal surfaces; paraselenic circles are caused by reflected moonlight. Other reflection phenomena frequently observed in the Antarctic include the earth shadow, the iceblink, the landblink, and the water sky. The earth shadow appears as dark bands and curved shadows that result from the projection of mountain peaks and other surface objects in the cloudless sky. The iceblink is a white or yellowish-white glare cast on the underside of clouds by considerable amounts of sea ice. Landblink is the land-ice counterpart of iceblink. Water sky is observed as the dark reflection of open water on the overcast. The sharply contrasting water sky and iceblink may sometimes be observed side by side from a great distance, thus strikingly outlining adjacent surface water and ice.

In this Area, multiple scattering by air molecules produces colorful displays both at sunrise and sunset. This phenomenon is observed away from the sun as both the blue or gray dark segment and the purplish anti-twilight arch. A bright twilight arc also rims the sky above the rising or setting sun.

The aurora australis and St. Elmo's fire are two types of electrical phenomena in this Area. The aurora, which is believed to be centered over Wilkes Land, is generally associated with the moonless Antarctic night. Therefore, with the onset of winter there is also an increase in the number of auroras reported, with as many as 17 having been observed in one winter month. Auroras may be recognized by their ray structure (rays, streams, draperies, corona) and their nebulous and variable appearance (homogeneous quiet arc, pulsating arc, homogeneous bands, pulsating surfaces, glow, nebula). Moreover, auroras may remain uniformly red, green, or purple, or assume a rapid succession of these colors. Such electrical outbursts are usually accompanied by interference with communications.

Another electrical phenomenon, St. Elmo's fire, is sometimes observed in summer, more rarely in winter. Because of its faintness, St. Elmo's fire is seen generally at night or under stormy conditions. These eerie flickers of blue light are caused by the unusual electrification of the air when the winds are strong and filled with drift snow. St. Elmo's fire may be observed on the tips of antennas, wind vanes, airplane wings, and ship masts.

H. Upper air

Upper-air observations are becoming increasingly significant because of present-day high ceilings of aircraft and rockets. There is also a demand for basic scientific investigation, for the meteorologist to explain the general circulation of the atmosphere, for the communication engineer to explain radar and radio propagation, and for the geophysicist to explain magnetic fluctuations.

The atmosphere over Antarctica is considerably colder at most flight altitudes than the U.S. standard atmosphere. The U.S. standard atmosphere is used to define gravity and the ever changing pressure and temperature of the atmosphere thereby establishing a basis for comparison and for calibration of instruments dependent upon the atmosphere. Upper-air wind roses for standard levels are presented for February and November in FIGURE 23-23; it should be noted that May and August data for Little America is included. Upper-air mean soundings representative of the months of February, May, August, and November are presented in FIGURES 23-24 and 23-25. In these figures the "Dog" values represent the difference between pressure altitude (feet) and the standard atmosphere. A schematic cross section of the standard atmosphere is included in FIGURE 23-24 along with the three layers, the troposphere, stratosphere, and ionosphere, which within themselves contain levels of operational significance.

1. Winds aloft

Over the Antarctic continent aircraft operations, covering the vast distances during the few months of continuous sunlight, have increased the demand for data of winds aloft. The wind data are used for forecasting the flight conditions suitable for such operations as aerial photo reconnaissance and for research of both an operational and a purely scientific nature. From wind data also the direction of air movement is determined as anticyclonic from the continent to the coastal waters in the lower troposphere, below 850 millibars (generally below 5,000 feet), especially during the winter season. These winds are cold and associated with the blizzards of Antarctica. Between approximately 7,000 and 16,000 feet this circulation becomes tran-

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sitional between the cold surface *high* and the cold *low* aloft.

Based on winds recorded at Little America the predominant winds in the lower troposphere during August are from the south and southwest becoming northeast in February. This indicates the seasonal influence of the *high* in the lower troposphere. Above the 500- and 400-millibar levels (about 16,000 to 20,000 feet) the winds blow predominantly from the westerly direction into the cold *low*. In comparison with the Northern Hemisphere the latitude of the belt of maximum wind speeds is closer to the Equator in the Southern Hemisphere. Also the increased zonal circulation in the Southern Hemisphere tends to reduce meandering of this belt as occurs over North America.

Over Antarctica the height of the lower mixed layer, the troposphere, extends from the surface to 29,400 feet (5.6 miles) during summer and becomes indefinite in winter. The composition of air in this layer is similar to standard air except for perhaps slightly less oxygen (less than 0.5%). The winds are influenced by convection, turbulent mixing, fronts, and inversions. The interaction of the cold continental *high* and the warm surface *lows* off the coast result in blizzards. In summer the top of the troposphere is associated with the maximum zonal wind and clear air turbulence which occurs near the tropopause, the boundary between the troposphere and the stratosphere. In the stratosphere, at the 200-millibar level (generally above 38,000 feet), the circulation is cyclonic and toward the continent. The wind speeds indicate increased zonal circulation in winter induced by thermal winds. The wind speed in summer reaches a maximum near the tropopause. The variability of winds at Little America indicates the interaction of several pressure regions. In the ionosphere wind speeds are unobserved over Antarctica.

The middle latitude westerlies surround the continent. The weaker westerly circulation over the Indian Ocean compared to that over the Australia and New Zealand indicates different zonal wind speeds along storm tracks. Rawin observations* from Port Stanley (12) indicate a maximum wind speed near the 250-millibar level in summer and increasing speeds with height in winter, indicating the continental influence over the islands of the southern oceans. The maximum wind speed in the upper air occurs near the tropopause in latitudes between 35° and 45°S. The core of maximum wind speed is called the jet stream and is associated with the break between the tropical and polar tropopauses. The jet stream's estimated speed of nearly 100 knots during winter decreases

* Wind aloft observations made by balloon and radio methods without optical aid.

to 70 knots during summer. During winter the jet stream is generally found at about 49,000 feet and during summer at about 39,000 feet.

The wind roses seldom indicate the speed of winds in the small core of the jet stream. Since the jet stream is associated with the tropopause, the level of maximum wind speed can be estimated from radiosonde data in the westerlies if the seasonal variation in vertical temperature lapse rate is considered.

2. Temperature and humidity aloft

The inaccessible interior of Antarctica is only partly understood because of inadequate facilities. Operation DEEPFREEZE now in progress is placing special emphasis on the Earth-science phase of research. The coasts have been explored by many expeditions whose data indicate one or more cold *highs* up to 6,000 to 7,000 feet above sea level. The inversion in the mean monthly winter temperature sounding (FIGURES 23-24 and 23-25) near Antarctica indicates a continental cold surface *high* or *highs* of dry stable air and a freezing level located near the surface. Sharp temperature and humidity inversions, as indicated in the individual radiosonde flights, bend and refract radar beams. This bending is expected to be more pronounced in winter by the sharp tropospheric temperature inversion. In summer the humidity contrast between the cold dry continental air and the warm moist air aloft may cause a sufficient decrease of water vapor content with altitude so that radar ranges are extended in the lower levels. In some instances the ranges may be increased to such an extent as to cause ducting.* In summer the inversion nearly disappears indicating a less pronounced and less extensive surface *high* over the Antarctic continent and the presence of surface heating by solar radiation.

Above the cold surface *high* there is a transitional zone between 7,000 and 16,000 feet in which the influence of the surface *high* decreases and the *low* aloft increases. This mean transitional zone is much thicker than on individual soundings. The gradual increase in temperature to near standard is one indication of this transition. Above the tropopause, about 29,400 feet, the temperature sounding is greatly different between the sunlight period of summer and the dark period of winter. In summer above the tropopause the temperature increases after reaching a minimum of about -50° C. In winter the lack of solar radiation in the shadow of the earth results in decreasing tem-

* Ducting occurs when a temperature and/or humidity discontinuity, causing inversions within a few thousand feet of the Earth's surface, results in relatively long radar ranges beyond the horizon.

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perature at the tropopause or the disappearance of the tropopause.

The stratosphere also differs from the standard isothermal stratified layer of temperature -55°C . In winter the temperature continues to decrease while in summer the temperature increases. At the 100-millibar level over Little America the average temperature is 43°C . colder in winter than in summer while at the 850-millibar level the difference is only 17°C . The stratosphere resembles the tropopause in composition. However, since most of the clouds and water vapor are below this level, solar radiation becomes more intense forming ozone in the upper part of the stratosphere. This increased concentration of ozone is important because the solar spectrum is terminated abruptly at 2,900 Å. (one Angstrom Unit is equal to 10^{-8} cm .) primarily by this form of oxygen. The substandard percent of oxygen at Antarctica may indicate less attenuation of solar energy. The short wavelength, high energy radiation is absorbed in the stratosphere over Antarctica as indicated in the Little America summer, thus explaining in part the increase in the temperature at an altitude of about 30 miles. Solar radiation absorbed by the ozone becomes the control of temperature. The usual radiosonde balloons burst before reaching this height in the Antarctic. The daytime "D" layer of electron density, that reflects very low frequency radio waves about 200,000 feet or nearly 50 miles in the temperate zone, is located near the top of the stratosphere. The height of this layer over Antarctica is unknown.

In the ionosphere the solar ultraviolet rays ionize the atmosphere whose pressure has decreased to that of the so-called "vacuum" of the electric light bulb. However, this seemingly unimportant upper level contains the "E" and "F" layers of electron density important to radio communication. The high temperature in the ionosphere is indicated by the spectra of nightglow and aurorae and by the measurements of the reflection coefficient as a function of the frequency of incident radio waves. Such measurements have been made outside the limits of Antarctica. Since the temperature depends upon the composition of the ionosphere, the temperature measured by various methods differs by as much as 500°K . (273°K . equals 0°C .) near the warmest point to about 2000°K . estimated near 1,300,000 feet or 250 miles, i.e., about the altitude obtained by a two-stage rocket. At this great height solar radiation tends to ionize all the elements of the atmosphere and meteors react with the atmosphere forming many ions.

In temperatures colder than -40°C . the radiosonde becomes unreliable for humidity measurements. This has limited the observations of rela-

tive humidity in the Antarctic since the surface temperature in winter approaches this limit.

Over the coastal waters the wedges of high pressure and *highs* from the Antarctic are modified rapidly. The temperature soundings quickly acquire the characteristics of those in the westerlies. The surface inversion no longer is as pronounced. The tropopause appears during all seasons. It is higher and colder over lower latitudes than over Little America (7). The tropopause slopes upward from less than 30,000 feet near the continent to about 55,000 feet near the subtropics between 30° and 40°S . where two tropopauses may occur at the same time. The thermal gradient especially in winter in the midlatitudes is the steepest at about the 300-millibar level. This thermal gradient results in thermal winds that add to the zonal circulation in the Southern Hemisphere. In summer this thermal gradient reverses in direction and becomes relatively flat. This thermal component explains in part the roaring forties and gales at the surface. The thermal gradient in the Southern Hemisphere is greater than that of the Northern Hemisphere. The tropopause also is lower over cold *lows* than over the *highs*.

I. Weather and military operations

Extreme cold, extensive cloudiness, frequent precipitation, gales, blizzards, persistently high humidity, extremely low humidity, and visibility peculiarities are all factors that affect military operations in the Area. On the continent the major deterrents are the extreme cold, frequent low cloudiness, white-out, and the dryness. Drifting snow becomes a problem when blizzards are frequent. In the offshore regions to the northern limit of the Area, maritime surface and air operations are affected by high humidity, extensive cloudiness, and strong winds associated with migratory *lows* in the westerlies. Owing to the diversity and rapid developments of modern military operations, this discussion mainly emphasizes the broad limitations imposed by the weather and is intended primarily for orientation.

1. Surface operations

a. CONTINENTAL

(1) *Trafficability* — The extreme weather conditions encountered by man in the Antarctic are the controlling factors which regulate trafficability. Of the weather elements, temperature and wind are the most important and are responsible for the overall severity of the weather that prevails at any given time.

During the winter season the pack extends northward to approximately 60°S . The width may range from a few hundred to 1,500 miles from the

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coastline, with the average being about 700 to 800 miles. In all, some 13,000,000 square miles, including the continent, are covered by ice during the winter months. In contrast, the ice area in summer is approximately 6,000,000 square miles less than in winter and its outer limits average about 200 miles seaward from the coast.

The entire Antarctic continent is almost completely covered by an icecap. It is estimated that the mean thickness of the glacier ice cover is about 2,000 feet and that $\frac{7}{8}$ of the earth's existing glacial ice is on the Antarctic continent. Except for mountain peaks and some valleys which may be warmed by the heat from the sun, there are very few bare surfaces in the Antarctic and almost no soil cover. The climatic influence on trafficability in the interior is less variable than in the coastal regions, partly as a result of the high elevation of the glacial plateau, some 6,000 to 11,000 feet. With the exception of explorers' routes to the pole, the interior has never been seen by man and is virtually unknown. The coast consists mainly of ice-covered rock or sheer vertical walls of solid ice rising anywhere from 10 to 200 feet above the adjacent sea ice. A characteristic topographic feature inland from the coast is the gentle, continuous glacial slope which often rises to heights of 8,000 to 10,000 feet.

On surfaces of snow and ice one of man's best means of surface travel for sustained marches has been the sled. In mountainous regions where steep slopes and dangerous surface features are ever present, daily distances by dog sled may average only 4 or 5 miles; on uninterrupted gentle glacier slopes and plateau regions, daily distances may average 12 to 15 miles; given favorable weather, maximum daily distances exceeding 25 miles are sometimes made over the relatively smooth ice shelf. It should be noted that surface travel by today's explorers is becoming more and more mechanized and that sustained marches on foot need be experienced only in times of emergency.

(2) *Clothing* — For planning purposes the Department of the Army publication T/A 21, "Clothing and Individual Equipment," prescribes seven worldwide clothing allowance zones, which are delineated according to specified ranges of mean monthly temperature. The military clothing requirements for the Area throughout the year may be associated with the following two basic climatic zones: 1) cold temperate (Zone VI), in which the mean monthly temperatures vary between 14° and 68°F.; 2) Arctic (Zone VII), i.e., Antarctic, in which the mean monthly temperature of the warmest month is less than 68° F. and that of the coldest month is less than 14° F.

The cold temperate zone includes the outer fringe of the continental ice shelf and all the open water regions to the north, whereas the Arctic (Antarctic) zone covers all of Antarctica and most of the permanent ice shelf regions. For specific clothing issues reference should be made to either T/A 21 or other appropriate service regulations that list the various components of the clothing assemblies along with the exact nomenclature and basis for issue.

Familiarity with the various types of Arctic clothing issue and the manner in which they should be worn in subfreezing weather can reduce loss due to frostbite, and, in extreme instances, minimize infection. Clothes in themselves do not provide heat; they merely hold in body heat. The wearing of several layers of medium-weight clothing can keep a person warmer than one heavy garment of the same thickness. Layers of air which become trapped between the clothes, and small air pockets within the fiber material provide better insulation by holding in body heat. The layer principle of wearing clothes allows a better adjustment of clothing through a wider range of temperatures. However, it should also be remembered that to utilize this principle effectively the outer garment should be of windproof and waterproof material in order to keep the cold outside air from penetrating through the inside layer of clothing.

(a) COLD-WEATHER ASSEMBLY — Cold-weather assemblies can be worn the year round along the northern perimeter of the permanent ice shelf. In this zone the air temperature regions are controlled generally by the presence of either a modified polar continental or maritime air mass. When under maritime influences, air temperatures remain in the vicinity of 27° to 34° F., whereas southerly continental winds usually lower temperatures an additional 5° to 10° F.

The basic clothing issue is primarily of woolen material. Such items as woolen trousers, high neck sweaters, field jackets, overcoats, flannel underwear, field caps, coveralls, mufflers, and gloves are a part of the cold-weather assembly. Leather or wind and waterproof items such as boots, shoes, gloves, and raincoats are also a part of the cold-weather assembly. In general, this type of clothing issue is typical of what one would expect to wear in a region such as the New England States in the wintertime.

(b) ARCTIC-WEATHER ASSEMBLY — The basic issue of Arctic-weather assembly is made up of part of the cold-weather assembly, with the addition of fur and other types of clothing equipment such as parkas, parka liners, parka hoods, parka

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trousers, shoepacks, outer mittens, mukluks, cheek protectors, Arctic sun glasses, face masks, and sleeping bag.

In the Antarctic regions, from the ice shelf edge to the interior, mean monthly temperatures vary from near freezing to below -40° or -50° F. throughout the year. Minimum daily temperatures have been observed colder than -80° F. on the continent.

(c) **SPECIAL CLOTHING PROBLEMS** — During snowy gales it is extremely important to dress in clothes that are wind resistant and waterproof. Exposed woolen material becomes heavy with powdery crystals in a matter of minutes and would become wringing wet if it became necessary to seek cover inside a tent where the air was warmer.

Adequate insulation between the iced surface and the inside of the sleeping bag is a necessity. Any transmission of body heat to the ice or snow will result in puddling and eventually the insulator will act as a conductor thereby transmitting the cold surface temperatures to the body.

Keeping clothing dry is a necessity in cold weather. Perspiration can be a more serious moisture problem than blowing snow. Regardless of outside temperature the body gives off about a pint of moisture a day, and with activity this rate increases appreciably. Control of the evaporation of perspiration can minimize freezing. If it is not possible to remove some of the outside clothing, one may resort to ventilation procedures by ejecting moist air at the waist, collar, and wrists. This procedure should be carried out even at the expense of momentary discomfort.

(3) **Storage** — On many Antarctic expeditions stored supplies are kept either snowfree or snowbound depending on the accessibility requirements. To counteract excessive drift, supplies may be kept snowfree by placing them on platforms or scaffolds. The air space beneath such structures is generally kept free of snow accumulation by the relatively strong winds. In such places as Little America where the frequency of gale-force winds is high, weatherproofing and anchoring of snow-free supplies is a necessity.

Drift has a tendency to accumulate in a long file on the lee side of obstacles on the surface. The number of such drifts can be reduced by grouping the supplies in rows parallel to the pre-

vailing wind direction. Burying is minimized within a group if the various elements are of similar heights. Also the effect of drifting between an object and the one to windward is minimized if the spacing between the objects is at least 30 times the height of the objects.

(4) **Shelter** — Even in the most favorable season adequate shelter is necessary for survival in the Antarctic. For inland travel by sled, minimum requirements are light tents of windproof material. As a rule two-man tents are used. Tents should be designed to be conspicuous in color with floors, sides, and entrance flap all in one piece. Flaps should also extend outside from the floor so that a firm anchorage, in addition to the guy ropes, can be made.

At permanent bases specially designed quarters, such as prefabs that are light, strong, and easily set up, are desirable. In such buildings the surface areas exposed to outside weather conditions are waterproof and double walled, with an air space between. Each wall section has its insulation material incased in aluminum foil, which simultaneously conserves and reflects the heat from within, and reflects and stops the cold penetrating air from the outside. Double flooring lined with rock wool, plus a circulating air space below the bottom side, is provided. Adequate inside ventilation is provided in the proximity of heating units, because of the danger of monoxide gas accumulation.

In areas of excessive snowdrift many explorers have lived quite comfortably underneath the drifts, where better insulation and protection against the elements are afforded.

(5) **Sunglare** — Since the dangers of snow blindness may be even greater on a cloudy day than on a clear one, the wearing of colored glasses at all times during the summer season is advisable. The increase poleward of duration of sunlight is illustrated by FIGURE 23-15, which lists the approximate dates based on mean latitudes when the sun is above the horizon for at least 12, 18, and 24 hours per day.

(6) **Wind chill** — In the Antarctic, wind chill resulting from the intense cold and strong winds is a problem that affects not only comfort but also the morale and safety of personnel. Whenever the air temperature is below freezing and

FIGURE 23-15. DAILY HOURS OF DAYLIGHT FOR SPECIFIED LATITUDES

LATITUDE	≥ 12 HOURS	≥ 18 HOURS	24 HOURS
85°-90°S.	19 Sept. - 25 Mar. ...	25 Sept. - 18 Mar. ...	26 Sept. - 17 Mar.
80°-85°S.	19 Sept. - 25 Mar. ...	2 Oct. - 10 Mar. ...	8 Oct. - 4 Mar.
75°-80°S.	19 Sept. - 25 Mar. ...	11 Oct. - 2 Mar. ...	21 Oct. - 23 Feb.
70°-75°S.	19 Sept. - 25 Mar. ...	22 Oct. - 18 Feb. ...	7 Nov. - 7 Feb.
65°-70°S.	19 Sept. - 25 Mar. ...	3 Nov. - 10 Feb. ...	1 Dec. - 15 Jan.

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the wind is greater than 15 knots, wind chill has a numbing effect, even through the warmest of clothing. Wind chill has a deleterious effect on the efficiency of personnel.

The relative degree to which wind chill affects human discomfort in cold weather is best illustrated as a function of temperature and windspeed. The tabulation below delineates weather conditions in which exposed flesh freezes and travel or working conditions become disagreeable:

TEMPERATURE °F.	WIND SPEED knots
20	40
10	17
0	9
-10	6
-20	4

The following tabulation defines conditions when exposed flesh freezes within one minute and travel or working conditions become dangerous:

TEMPERATURE °F.	WIND SPEED knots
-10	40
-20	22
-30	13
-40	9

At extremely cold temperatures the wind and temperature effect may only account for two-thirds of the heat loss from the body. For example, in weather as cold as -40° F. about one-third of the heat loss from the body occurs through the lungs in the process of breathing.

On a calm day moving about in an open vehicle can produce the same chilling effect as a blowing wind. Under calm and subfreezing weather conditions, the degree of chill can be doubled in a vehicle moving 3 knots and tripled in a vehicle moving 15 knots.

(7) *Blizzards* — Blizzards, very common over the Antarctic continent, occur most often from February through October and somewhat less frequently from November through January. They may come up very suddenly and continue for days without interruption. The experience of those who have attempted to travel in these blizzards on sled trips shows that blizzards often make travel impossible for as much as one-half to two-thirds of their duration. The approach of a blizzard is usually heralded by a light high overcast which rapidly thickens and darkens. Sometimes the approach of a blizzard may be watched, as landmarks are blotted out by advancing storms and strong winds.

Some of the characteristics of the Antarctic blizzard are very low visibilities (often zero), strong winds, and conditions similar to white-out with the addition of fine driving snow. This fine

driving snow is one more of the trying features of these blizzards because it gets into everything not carefully secured.

The most important dangers connected with these blizzards, aside from discomfort, are the possibilities of drifting off course and overshooting or missing a camp site or depot, falling into invisible glacial crevasses or lightly bridged crevasses, or driving over the edge of a sharply defined escarpment. This last hazard is a very real one in parts of the Palmer Peninsula, much of which is a plateau edged by steep sides with perpendicular drops of hundreds of feet. Furthermore the Palmer Peninsula is known to have frequent and severe blizzards.

b. *MARITIME* — In general the ocean waters of the Area are divided into two distinct regions. The Antarctic Convergence serves as a natural boundary between the cold Antarctic and subantarctic waters and encircles the globe in a meandering manner between 48° and 61°S.

This zone of discontinuity is marked by a steep water-temperature gradient. Local weather conditions as well as the marine life of the contrasting waters are distinctively different in character, and the line of demarkation is observed where the cold Antarctic waters sink beneath the relatively warmer subantarctic waters of the adjacent Atlantic, Pacific, and Indian Oceans. The mean position of this boundary lies in the zone of westerly wind circulation. Some 5° to 10° south of this boundary, at an approximate mean position of 65°S., the mean air circulation shifts to a predominant easterly flow in the vicinity of pack ice. There is a distinct contrast in weather conditions between the two predominant wind circulation systems.

In the zone of westerlies the major deterrents to ships of all types are the high waves and strong winds that relentlessly persist. The comparison of the two general wind systems shows that the westerlies are characterized by persistently strong winds, having monthly means usually in excess of 20 knots and of gale proportion about one-third of the time; less cloudiness, low ceilings averaging 1,000 to 2,000 feet with the percent of cloud cover increasing southward; and relatively warm air temperature, which in the vicinity of 50°S., averages 46° to 50° F. and decreases toward the pole at a rate of approximately 1° F. for every degree of latitude.

In the zone of easterlies the main deterrents to all ships are the ice conditions. For example, it is virtually impossible for supply ships to penetrate the pack ice as far as the permanent ice shelf and coastal areas without the assistance of ice-breakers. As one approaches the polar icepack in

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the zone of easterly winds, the following comparisons to the westerlies is noted: although winds are weaker, strong gravity winds close to the coastal areas may blow with hurricane force at times; cloudiness increases in the vicinity of the icepack and ice shelf, with ceilings averaging 450 to 2,000 feet; and mean air temperature decreases to approximately 28° F. along the outer limits of the ice shelf.

(1) *Navigation through pack ice* — Experience has shown that paths through a heavily iced region tend to stay open longer when the lead ship travels in a straight line. As one approaches Antarctica and iceblink is seen, it is a sure sign that pack ice is not too far off. Likewise, the appearance of water sky is a sign that open water is nearby. Ships in convoy should be about three or four ship lengths apart as cross winds or pressure ice can quickly close channels. Reconnaissance by helicopter or longer range reconnaissance aircraft can be employed to determine the best routes that will clear most of the heavy icefields, pressure ice, and icebergs that are floating in the pack.

(2) *Landing operations* — Large scale operations, such as Operation HIGHJUMP, may require supply ships to penetrate the ice barrier to a considerable distance before unloading operations commence. The assistance of an icebreaker to plow the way through the ice pack, ranging from a mixture of brash and drift ice to consolidated pack, minimizes the chance of unreinforced ships being stopped far short of their goal. The discharge of cargo from the supply ships must be accomplished despite frequent interruptions from weather and sea conditions. The best wharfing facilities are generally found in regions of fast bay ice, as the ship may be moored in a more normal manner permitting a fast and safe discharge of cargo. Time may often be an important factor in the discharge of cargo, especially when there is the threat of ice closing in as a result of a sudden change in weather. Speed is more important than the orderliness or arrangement of the supplies.

Landing operations at many of the islands in the northern part of the Area are generally difficult and dangerous, because few natural harbors exist. Some islands, such as Heard Island, are mountainous and fierce downslope winds of gale force are often experienced along the coast. Under such conditions unloading operations are carried on from offshore anchorages by small craft. Wind directions may reverse in a matter of a few hours, increasing the difficulty of landing operations.

Successful mooring of ships, not in the icebreaker class, to the ice shelf is especially dependent upon weather conditions. Appreciable changes in either wind direction or force may require moving the mooring lines attached to the "dead men" sunk in the ice, whenever the ice shows signs of breaking up or drifting out towards open water.

(3) *Superstructure icing* — In recent years superstructure or ship icing has become a serious problem to the Navy, since operational interests have become focused on polar areas. Ship icing results mainly from ocean spray when the air temperature is sufficiently cold (below approximately 27° F.) to cause freezing on contact with the superstructure. Other types of ice accumulation, such as freezing precipitation, are less frequent than the ocean spray variety. The intensity of expected ship icing conditions at subfreezing temperatures varies proportionately with wind speed.

At Beaufort force 5 (17 through 21 knots), which may be defined as a fresh breeze, spray tends to be blown from the breaking wave crests. Spray associated with winds of Beaufort 5 is slight. The amount or intensity of sea spray increases proportionately with the intensity of the wind. At Beaufort 7 (28 through 33 knots), which is defined as a moderate breeze, the amount of spray starts to become more noticeable. At Beaufort 9 (41 through 47 knots), which is defined as a strong gale, spray increases to the point where it may affect visibility. At hurricane force, Beaufort 12 (64 knots or greater), the air is filled with spray and foam to the point where visibility is seriously affected because of the driving spray. The following tabulation based upon the above parameters shows an arbitrary classification of ship icing conditions as a function of windspeed, when air temperatures are below 27° F.:

BEAUFORT FORCE	WIND SPEED (KNOTS)	SHIP ICING CONDITION
5 through 6	17 through 27	Light
7 through 8	28 through 40	Moderate
9 through 12	41 or more	Heavy

Preventive measures should always be taken to combat ship icing whenever it occurs. The weight of excessive accumulation is enormous. One inch of topside icing on a large destroyer may weigh as much as 80 tons. At times a change in ship speed or direction can either be a contributing or a noncontributing factor in producing ship icing, as the wind effect associated with spray conditions is relative to the wind passing by the ship. For example, a ship headed into a 25-knot wind at a speed of 20 knots would produce heavy spray creating a serious operational hazard, whereas considerably less spray would be encountered if the ship was headed downwind.

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(4) *Steam fog* — Steam fog, generally referred to as Arctic sea smoke, commonly occurs over the water areas in the vicinity of the ice shelf of Antarctica. Other than a restriction to visibility, it is not considered a major hazard to military operations. Generally steam fog is shallow, usually 50 to 100 feet in height.

(5) *Submarine operations* — When surfacing is necessary and weather conditions are adverse, i.e., strong winds and temperatures below 27° F., superstructure icing may become a serious operational hazard. Under these conditions the degree of icing is proportional to the strength of the wind and the relative coldness of the air. Snorkeling is the best defense against superstructure icing. It is possible to remove about 4 inches of superstructure icing in an hour's time by snorkeling below the surface or by diving in the warmer water below the surface layer of cold water.

2. Carrier operations

The Antarctic presents many restrictive problems to aircraft carrier operations. One of the major problems is the pack ice which in winter extends northward to about 55°S. in the Atlantic Ocean and 60°S. in the Pacific Ocean. Between 50° to 60°S. the westerlies average 20 knots. Strong gusty winds and frequent gales (25% to 35% of observations) occur along the southern extent of the subtropical high-pressure areas. This zone lies just north of the ice boundary, and the resulting rough seas, heavy swells, and structural icing affect carrier operations. Storms are violent and are likely to come up with little warning. Icing conditions almost always exist, and extensive fogs and low overcasts are frequent. In carrier operations, where efficiency of flight deck crews must be maintained at a high level, wind chill is a serious problem. As a result routine tasks become difficult and time consuming. Cold weather operations require more extensive inspection and more frequent servicing of aircraft than comparable operations in warm regions. Experience has shown that the additional demands placed on flight deck crews may at times reduce the availability of aircraft for efficient air operations by as much as one-half.

a. *PREPARATION OF PLANES FOR FLIGHT* — If airplanes are left on the flight deck, they must be thoroughly protected against the strong winds, low temperatures, and precipitation associated with storms; otherwise, the control surfaces will be covered with snow, ice, or frost.

The warm hangar deck has been found to be especially useful in preparing planes for flight. However, moisture in the air of a warm hangar deck often condenses on the cold metal surfaces of an airplane when brought down from the flight

deck. This moisture may freeze if the plane is returned to the flight deck while wet. Such moisture can be removed from exterior parts of planes but on inner parts, such as machine guns, it can only be removed by dismantling the gun.

Still another problem to be considered is fuel expansion. Fuel tanks, when filled to capacity on flight deck, can overflow when the plane is sent to the warm hangar deck.

b. *LAUNCHING AND RECOVERY* — Since safe and efficient operation of aircraft is only possible with a clear flight deck, snow and ice removal is of prime importance. It has been found that by removing the snow during the storm rather than after the storm delay in launching aircraft could be minimized. Icy decks and the effect of extremely cold temperatures on personnel impede plane handling. During high winds, plane handling is dangerous to the safety of personnel.

3. Military air operations

The use of aircraft in the Antarctic is vital not only for replenishment operations but also for such military operations as photographic aerial reconnaissance, visual reconnaissance to facilitate ice-breaker navigation, and magnetic research. Frequent blizzards, low ceilings, and reduced visibilities are hazardous to aircraft operation; nevertheless, the use of aircraft in transporting supplies and personnel to remote sites is necessary where the surface trafficability is restricted by severe climate and rugged terrain. The use of large air bases at such locations as near McMurdo Sound (17), in preference to sites on continents or islands to the north, saves at least 10 to 14 hours of time and fuel on any military or replenishment operation over the continent.

The effects of weather and climate are significant in regard to both aircraft and runway maintenance. Factors such as the formation of pressure ridges near runways located on sea ice, the effect of extreme cold on engines, and the frequent and rapid accumulation of drift snow, all add to the problem of upkeep. Nevertheless, there are numerous suitable landing sites for light and medium-type aircraft.

Plans for the coming International Geophysical Year 1957-58, including Operation DEEPFREEZE, are underway and the scope of operations involved far exceeds anything attempted to date. Included in the plans are the construction of an interior airstrip on the glacial plateau that will permit the heavier-type wheeled planes to land in the Antarctic for the first time. In the interior at elevations above 5,000 feet, normal takeoff would require longer runways because of the relatively low air density. With heavy loads, jet-assisted takeoffs (Jato) might be necessary. The recent develop-

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ment of engineering equipment, capable of compacting loose deep snow into a very hard surface, makes possible the construction of runways long enough and safe enough for almost any type of aircraft. The location of these runway sites would do much to accelerate replenishment of supplies, photo-reconnaissance, and other types of military operations. The following is a discussion of the important weather aspects that affect present air operations in the Antarctic.

a. FLYING CONDITIONS IN THE ICE-SHELF REGIONS — During the summer season most of the nearshore, coastal, and permanent ice-shelf regions of the Antarctic experience a mean easterly wind-flow. This is in contrast to the predominant westerly flow over the open water approximately 100 miles north of the outer edge of the ice shelf. Associated with these easterly winds are low overcast, broken stratus, or stratocumulus clouds which are observed about 80% to 90% of the time. Ceilings normally range from 450 to 2,000 feet. Low ceilings account for either instrument or closed flying conditions about 25% to 35% of the time. Suitable flying conditions along the nearshore areas, under maritime influence, generally last only a few hours to a few days at a time. The best flying weather occurs during the period from September through February. Regions of low ceilings, causing hazardous landing conditions, are generally found along the periphery of the continental high.

In other areas, such as the Ross and Weddell Seas, where the circular contour of the coastline is indented, the mean easterly flow shifts to a southerly direction. This wind shift occurs as the mean airflow over these seas descends from the inland plateau. Contact-flying conditions in these areas are more frequent than along the coastal perimeter. Over the ice shelf in the Weddell and Ross Seas, low clouds with ceilings under 2,000 feet occur less than 15% of the time, and contact-flying conditions prevail about 90% of the time. Very little convective activity takes place over the ice-shelf portions of these large sea areas. This fact accounts for the small percentage of low-level cumulus cloud formation. Ceilings above 10,000 feet are observed more than 50% of the time.

b. AIRCRAFT ICING — In the Antarctic, aircraft icing at all flight levels is to be expected in all clouds south of the open water areas. Prior to the advent of the more recent polar flying operations, it was believed that ice accretion at air temperatures below -10° F. was not possible. It was then thought that the moisture present at such cold temperatures would either be in the form of dry ice or too small amount to be significant. Actually, recent polar air operations have revealed that clear icing in convective cumuliform clouds occurs at temperatures below -30° F. from contact with supercooled

water droplets. It is also believed that ice crystal clouds with temperatures below -10° F. may produce clear icing through impact, because the additional heat thus generated is capable of melting the ice crystals to liquid form.

Generally speaking rime or clear icing conditions are considered to be the most hazardous for aircraft in flight. Other types of icing conditions such as rime or glazed frost offer no serious hazard unless they affect the pilot's visibility by excessive accretion over the windshield area. The most serious icing conditions are those found in convective clouds composed of water droplets having air temperatures within the range of 32° to 20° F. The larger the droplet size the more serious the ice accretion problem becomes as the drops merge and spread out upon contact, and layer freezing of the particles takes place generally in the form of clear ice. The accumulation of clear ice on an aircraft in flight is considered more hazardous than rime ice because the formation of clear ice affects a larger surface area on the aircraft thereby creating a greater weight problem. Rime ice is usually associated with colder air temperatures and thinner cloud formation where the water droplets freeze individually after contact without spreading out. Rime ice accumulates mainly on the leading edges of the aircraft, is closely compacted, and has a white opaque appearance. The adhering qualities of rime ice are not as great as clear ice and therefore can be removed from the aircraft more readily.

Aircraft icing, except in very active cumulus convective clouds, generally is confined to a shallow layer very seldom exceeding 8,000 feet in thickness. Aircraft icing can sometimes be avoided by seeking another altitude. It generally is advisable to climb if there is sufficient power for a rapid ascent. It should be remembered that ice accumulation is less at colder temperatures and that a climb of 8,000 feet is almost always successful in reaching an ice-free level. However, if icing occurs in a broken sky condition or in clouds and if it is known that there is either clear air or temperature above freezing at a lower altitude, then a descent should be made provided there is adequate clearance of high ground.

c. METEOROLOGICAL FACILITIES — Accurate portrayal of synoptic conditions in the Antarctic is oftentimes difficult, mainly because of the lack of observed data. The complete absence of permanent weather stations south of 60° S. places the responsibility for providing the necessary meteorological coverage for operational forecasts on task forces or expeditions in the Area. This along with a limited number of climatological records places the emphasis on such things as individual experience, rules of thumb, single station analysis, and the skill of the individual forecaster when operational fore-

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casts are required. Before reliable operational forecasts in the Antarctic regions can be made, a network of meteorological observational stations along the coast and interior of Antarctica plus adequate coverage over the ocean areas to 50°S. will be necessary.

Around the continental perimeter, pressure tendencies can be used as a forecasting tool. Migratory lows frequently move at regular intervals around the continent and their passage may be predicted by falling pressures. In addition, cloud systems associated with frontal weather may be utilized advantageously for short-range forecasts. Frontal weather encountered in the Antarctic is similar in many aspects to weather systems found in more northern latitudes.

d. AIR NAVIGATION — Polar navigation is considered as difficult as that in any part of the world. The problems of distortion as on Mercator Charts and of converging meridians as on Polar Charts have been partially solved by superimposing rectangular grid systems. Since much of Antarctica is unmapped and many areas have been mapped only once, the problem of insufficient reliability and detail is paramount. Standard navigational aids for planes in flight have been limited for the most part to those provided by expeditions and task forces operating on a temporary basis.

In Antarctica, polar weather and other atmospheric phenomena affect navigation in many ways that are unusual. The foremost of these is the problem of magnetic disturbances that virtually exclude the use of a conventional magnetic compass as a reliable navigation instrument. As one approaches the magnetic pole the horizontal force component of the magnetic field becomes relatively weak. On the other hand the vertical force component of the magnetic field becomes relatively strong. Thus, a needle compass is acted upon primarily by a vertical force and tends to dip. This phenomenon is so noticeable during a compass swing that the needle fails to respond to any change of direction. Since the Antarctic is an area of frequent magnetic storms, the needle may respond to the violent changes in the horizontal force and thus spin erratically. The fluxgate compass may be useful in times of magnetic quiet; however, it too cannot be relied upon in periods of magnetic storms. The astrocompass and gyrocompass are the more useful and reliable for polar flying because their principle of operation is not dependent upon the earth's magnetic field. The chief advantage of the astrocompass lies in the fact that true heading rather than magnetic heading can be determined directly so that only the wind drift of the aircraft need be obtained to determine the true course or track of the aircraft. The main disadvantage in

using the astrocompass is that it becomes useless under overcast conditions.

In addition to its use as a standard means of navigation radar is especially desirable whenever visibilities are poor, whenever undercast conditions prevail requiring that letdowns be made through clouds, and whenever the detection of high obstacles is necessary.

e. SEAPLANES — Takeoff and landing sites for seaplanes require only the location of open water with adequate facilities nearby for maintenance and servicing. Another advantage to be considered in seaplane operations is the temperature factor. The warmer air temperatures with monthly means above freezing over the open water areas provide a distinct advantage over conventional land-based aircraft where surface operations must be carried out in subfreezing weather. Takeoffs and landings are generally made parallel to the swell when surface winds are less than 15 knots. When surface winds are approximately 15 to 20 knots a downswell landing is preferred. For winds in excess of 20 knots, wind direction becomes an important factor in determining the aircraft heading in making a landing. Landing into the swell may have to be made when the wind exceeds 20 knots. This type of landing is considered the most hazardous and the best landing procedures often depend upon pilot experience. Whenever takeoffs are made in subfreezing air temperatures, ice may form on the aircraft from the resultant spray. However, the main difficulty experienced is usually the clogging of the static openings of the pressure altimeters. A couple hours or more may be required to melt the ice or for it to be peeled off by the wind. Letdowns through the low overcast cloud decks that normally prevail may require a radar landing approach in order to avoid drifting bergs or other large ice obstructions that cannot be seen soon enough by eye.

f. HELICOPTERS — Helicopters have been lost on at least two Antarctic expeditions in weather that was not considered dangerous for conventional-type aircraft. When a helicopter is on the ground, the danger of damage resulting from the leverage effect of the wind against the blade is important. Takeoffs or landings whenever surface winds exceed 20 knots require the proper safety precautions. At many stations a padded handle is used to hold the blades in place prior to takeoff or after landing.

Flying a helicopter under conditions of snow-blink is considered dangerous. While in the air, fogging on the inside of the cabin or frosting on the outside may occur when in the proximity of clouds. Fogging under these conditions may usually be dissipated by opening a window; however, the dis-

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sipation of the frost is best accomplished by retreating approximately 400 feet from the clouded area. Sometimes both fogging and frosting occur simultaneously when flying beneath a low overcast when the air temperature is a few degrees below freezing; lowering the altitude may not overcome this difficulty and it may be necessary to back-track from the clouded area.

g. LANDING ON SEA ICE — The temperature, thickness, and age of ice are important factors involved in determining suitable landing sites for land-based aircraft. The minimum thickness of sea ice, for very light planes, grossing less than 5,000 pounds, is estimated to be 10 inches. The following tabulation may be used as an indicator of basic minimum ice thickness requirements for aircraft having wheels:

GROSS-WEIGHT OF AIRCRAFT	MINIMUM ICE THICKNESS
pounds	feet
10,000	1½ - 2
20,000	2 - 2½
40,000	2½ - 4
60,000	3 - 4½
80,000	3½ - 5½
100,000	4 - 6
150,000	5 - 8
200,000	6 - 9

It should be noted that this table is based on sea ice at least one year old at a temperature of 16° F. or less and for static loading conditions in areas far from the edge of the ice field. (For a more detailed explanation and coverage of this subject reference is made to the following naval publication: Navdocks P-17, "Cold-Weather Engineering," Chapter VI to X, U.S. Navy Engineer Corps, Bureau of Yards and Docks, 1948-49.)

The following rules of thumb may be employed, when using the above table, to take into consideration other situations that may occur: 1) For areas near the ice field edge, the table may be used providing the gross weight values are reduced by approximately one-third. 2) When air temperatures are warmer than 16° F., the ice thickness values should be increased approximately one-fourth. 3) For aircraft using skis, the ice thickness values should be reduced approximately one-sixth. 4) For young sea ice less than one year, the ice thickness values should be increased approximately two-thirds.

h. MAINTENANCE OF LANDING STRIP — Once a landing site has been selected snowdrift becomes a problem. As drifts form across the runway they must be removed or spread out by a bulldozer or scraper. Over a period of time the constant scraping and spreading out of excess snow results in its becoming compacted over the runway forming a natural hard landing surface. If this accumula-

tion of compacted snow exceeds five inches, the excess snow should be bladed off.

Parking an aircraft on snow or ice may result in a freeze-in, because the added pressure on the wheels or skis may create sufficient heat to thaw the ice or snow which soon refreezes. For this reason it is advisable always to taxi the aircraft upon a wooden or metal platform which also distributes the weight of the aircraft to better advantage.

i. SNOWBLINK AND WHITE-OUT — Severe snowblink is an optical phenomenon that occurs in the Antarctic and is considered a very hazardous operational flight problem. It occurs on bright days when there is a thin stratus overcast. The scattering effect of the light rays passing through the thin stratus deck makes it impossible to discern the horizon or to focus the eyes on any white object. Snow landings under these conditions should only be made if dark objects in the vicinity of the landing area can be used to help determine the horizon and level of the landing area.

When flying over the continent it is frequently difficult to distinguish the horizon because of the typical blending of the clouds with the snow or ice surface. During Operation HIGHJUMP this phenomenon, referred to as white-out, was responsible for the loss of a helicopter which flew into the glacier.

J. List of sources

1. ARCTOWSKI, HENRYK. "Météorologie, Rapport sur les Observations Météorologiques Horaires; Résultats du Voyage du S. Y. *Belgica* en 1897 - 1898-1899" [Meteorology, report on hourly meteorological observations, results of the voyage of the S. Y. *Belgica* in 1897 - 1898-1899], *Expédition Antarctique Belge, Rapports Scientifiques*. Tomes 3-4, parties 1, 2, 3, 4, and 5, 1903-1904. Various pagings.
2. BARKOW, E. "Die Meteorologischen Ergebnisse der 2. Britischen Antarktischen Expedition, 1910 bis 1913" [Meteorological results of the 2nd British Antarctic Expedition, 1910 to 1913], *Annalen der Hydrographie und Maritimen Meteorologie*, Jahrg. 48, p. 305-315; 347-356, 1921.
3. ———. "Die Ergebnisse der Meteorologischen Beobachtungen der Deutschen Antarktischen Expedition 1911-1912" [Results of meteorological observations of the German Antarctic Expedition 1911-1912], *Veröffentlichungen des Preussischen Meteorologischen Instituts*, Bd. 7, nr. 6, p. 1-166, 1924.
4. BELLAMY, J. C. "The Use of Pressure Altitude and Altimeter Corrections in Meteorology," *Journal of Meteorology*, vol. 2, no. 1, p. 1-79, 1945.
5. BROOKS, C. E. P., AND CARRUTHERS, N. *Handbook of Statistical Methods in Meteorology*. M.O. 538. Great Britain, Meteorological Office. London. 1953. 412 p.
6. COURT, ARNOLD. "Tropopause Disappearance During the Antarctic Winter," *Bulletin of the American Meteorological Society*, vol. 23, no. 5, p. 220-238, 1942.

~~CONFIDENTIAL~~

NAVY - JANUARY 1956

MILITARY GEOGRAPHY

CONFIDENTIAL

7. ———. "Meteorological Data for Little America III," *Monthly Weather Review, Supplement No. 48*, 1949. 150 p.
8. ———. "Antarctic Atmospheric Circulation," *Compendium of Meteorology*, Malone, T. F., ed. P. 917-941. Boston: American Meteorological Society. 1951. 1334 p.
9. DORSEY, H. G. "Meteorology at East Base of U. S. Antarctic Expedition, 1939-1941," *Bulletin of the American Meteorological Society*, vol. 22, no. 10, p. 389-392, 1941.
10. DRYGALSKI, E. VON. "Deutsche Südpolar-Expedition auf dem Schiff GAUSS" [German South Polar Expedition on the ship GAUSS], *Veröffentlichungen des Instituts für Meereskunde und des Geographischen Instituts an der Universität Berlin*, No. 5, p. 1-181, 1903.
11. GENTILI, J. "Air Masses of the Southern Hemisphere," *Weather*, vol. 4, no. 8, p. 258-261. London. 1949.
12. GERSON, N. C. "The Atmosphere," *U.S. Air Force. Geophysics Research Directorate. Cambridge Research Center. Air Research and Development Command. Surveys in Geophysics No. 73*. P. 1-62, 1955.
13. GIAEVER, JOHN. *The White Desert*. London: Chatto and Windus. 1954. 304 p.
14. GIBBS, W. J. "A Comparison of Hemispheric Circulations with Particular Reference to the Western Pacific," *Quarterly Journal of the Royal Meteorological Society*, vol. 79, no. 339, p. 121-136. London. 1953.
15. GIBBS, W. J., GOTLEY, A. V., AND MARTIN, A. R. "Meteorology: Heard and Macquarie Islands, 1948," *Australian National Antarctic Research Expeditions*, Ser. D, vol. 1, pt. 1(a), p. 1-109, 1950.
16. GORDON, A. H. "Waterspouts," *The Marine Observer*, vol. 21, no. 151, p. 47-60, 1951.
17. GREAT BRITAIN, HYDROGRAPHIC DEPARTMENT. *South America Pilot*. Ed. 13, pt. 2. London. 1942. 348 p.
18. GRIMMINGER, G. "Preliminary Results of Pilot-Balloon Ascents at Little America," *Monthly Weather Review*, vol. 67, no. 6, p. 172-176, 1939.
19. ———. "Meteorological Results of the Byrd Antarctic Expeditions 1928-1930, 1933-1935; Summaries of Data," *Monthly Weather Review, Supplement No. 42*, 1941. 106 p.
20. GRIMMINGER, G., AND HAINES, W. C. "Meteorological Results of the Byrd Antarctic Expeditions 1928-1930, 1933-1935; Tables," *Monthly Weather Review, Supplement No. 41*, 1939. 377 p.
21. HAINES, W. C. "Winds of the Antarctic," *Transactions of the American Geophysical Union*. No. 13, p. 124-128. 1932.
22. HARRISON, H. T. "Antarctic Meteorology," *Monthly Weather Review*, vol. 59, no. 2, p. 70-73, 1931.
23. HAURWITZ, BERNHARD, AND AUSTIN, J. M. *Climatology*. New York: McGraw-Hill. 1944. 410 p.
24. HUTCHINGS, J. W. "A Meridional Atmospheric Cross Section for an Oceanic Region," *Journal of Meteorology*, vol. 7, no. 2, p. 94-100, 1950.
25. HUXLEY, LEONARD. *Scott's Last Expedition*. Vol. 1. New York: Dodd, Mead and Company. 1913. 443 p.
26. JALU, R. "Expédition Antarctique Française, 1948-1949; Section Météorologie, Rapport Préliminaire; Premier Exposé des Résultats" [French Antarctic Expedition, 1948-1949; Meteorology section, preliminary report; first account of results]. France. Ministère des Travaux Publics des Transports et du Tourisme. Memorial de la Meteorologie Nationale, No. 33. Paris. 1950. 31 p.
27. JOHNSON, J. O. *Physical Meteorology*. New York: John Wiley; Cambridge: Massachusetts Institute of Technology. 1954. 393 p.
28. KIDSON, EDWARD. "Meteorology; Discussions of Observations at Adélie Land, Queen Mary Land and MacQuarie Islands," *Australasian Antarctic Expedition, 1911-1914, Scientific Reports*, Ser. B, vol. 6, p. 1-121, 1946.
29. KÜHLBRODT, ERICH, AND REGER, JOSEF. *Deutsche Atlantische METEOR Expedition die Meteorologischen Beobachtungen, Methoden, Beobachtungsmaterial und Ergebnisse, erste Lieferung Abschnitt Beobachtungsmethoden und das Beobachtungsmaterial* [German Atlantic METEOR Expedition Meteorological observations; methods, observational material and results], Bd. 14, no. 1, p. 1-212. Berlin. 1936.
30. LAMB, H. H. "A Meteorologist's Experiences on a Floating Whaling Factory in the Antarctic," *The Marine Observer*, vol. 17, no. 138, p. 75-83, 1947.
31. LAW, P. G., ed. "Meteorology; Heard and Macquarie Islands, 1949," *Australian National Antarctic Research Expeditions*, Ser. D, vol. 2, p. 1-135; vol. 3, p. 1-142, 1953.
32. LIST, ROBERT J. *Smithsonian Meteorological Tables*. Smithsonian Miscellaneous Collections, Publication No. 4014. Vol. 114. 1951. 527 p.
33. LOEWE, F., AND RADOK, U. "A Meridional Aerological Cross Section in the Southwest Pacific," *Journal of Meteorology*, vol. 7, no. 1, p. 58-65, 1950.
34. LOON, HARRY VAN. "A Note on Meridional Atmospheric Cross Sections in the Southern Atmosphere," *NOTOS*, vol. 4, no. 2, p. 127-129, 1955.
35. MADIGAN, C. T. "Meteorology; Tabulated and Reduced Records of the Cape Denison Station, Adélie Land," *Australasian Antarctic Expedition, 1911-1914, Scientific Reports*, Ser. B, vol. 4, p. 1-286, 1929.
36. MATHA, A., AND REY, J. J. *Expédition Française, 1903-1905; Hydrographie Physique du Globe* [French Antarctic Expedition, 1903-1905; physical hydrography of the earth]. Paris. 1911. 615 p.
37. MAWSON, DOUGLAS. "Meteorology; Records of the Queen Mary Land Station; Meteorological Log of the S. Y. AURORA; Sledge Journey Weather Records," *Australasian Antarctic Expedition, 1911-1914, Scientific Reports*, Ser. B, vol. 5, pts. 1-3, p. 1-281, 1940.
38. MEINARDUS, W. "Klimakunde der Antarktis [Climatology of the Antarctic]," *Handbuch der Klimatologie*, Bd. 4, tl. U, p. 1-133, 1938.
39. ———. "Meteorologische Ergebnisse der Winterstation des GAUSS, 1902-1903 [Meteorological results of the winter station of the GAUSS, 1902-1903], *Deutsche Südpolar Expedition, 1901-1903*, Bd. 4, hft. 1, p. 1-452. Berlin: Druck und Verlag von Georg Reimer. 1909.
40. MOHN, H. "Meteorology," *Roald Amundsen's Antarctic Expedition, Scientific Results*. Kristiania: I Kommission Hos Jacob Dybwad. 1915. 78 p.
41. MOSSMAN, R. C. "Report on the Scientific Results of the Voyage of S. Y. SCOTIA during the years 1902, 1903, and 1904; Meteorology," *Scottish National Antarctic Expedition*, Vol. 2, pt. 1, p. 1-306, 1907.
42. NEUBERGER, HANS. "General Meteorological Optics," *Compendium of Meteorology*, Malone, T. F., ed. P. 61-78. Boston: American Meteorological Society. 1951. 1334 p.
43. PEPPER, J. *The Meteorology of the Falkland Islands and Dependencies, 1944-1950*. Falkland Islands Meteorological Service. London. 1954. 249 p.

CONFIDENTIAL

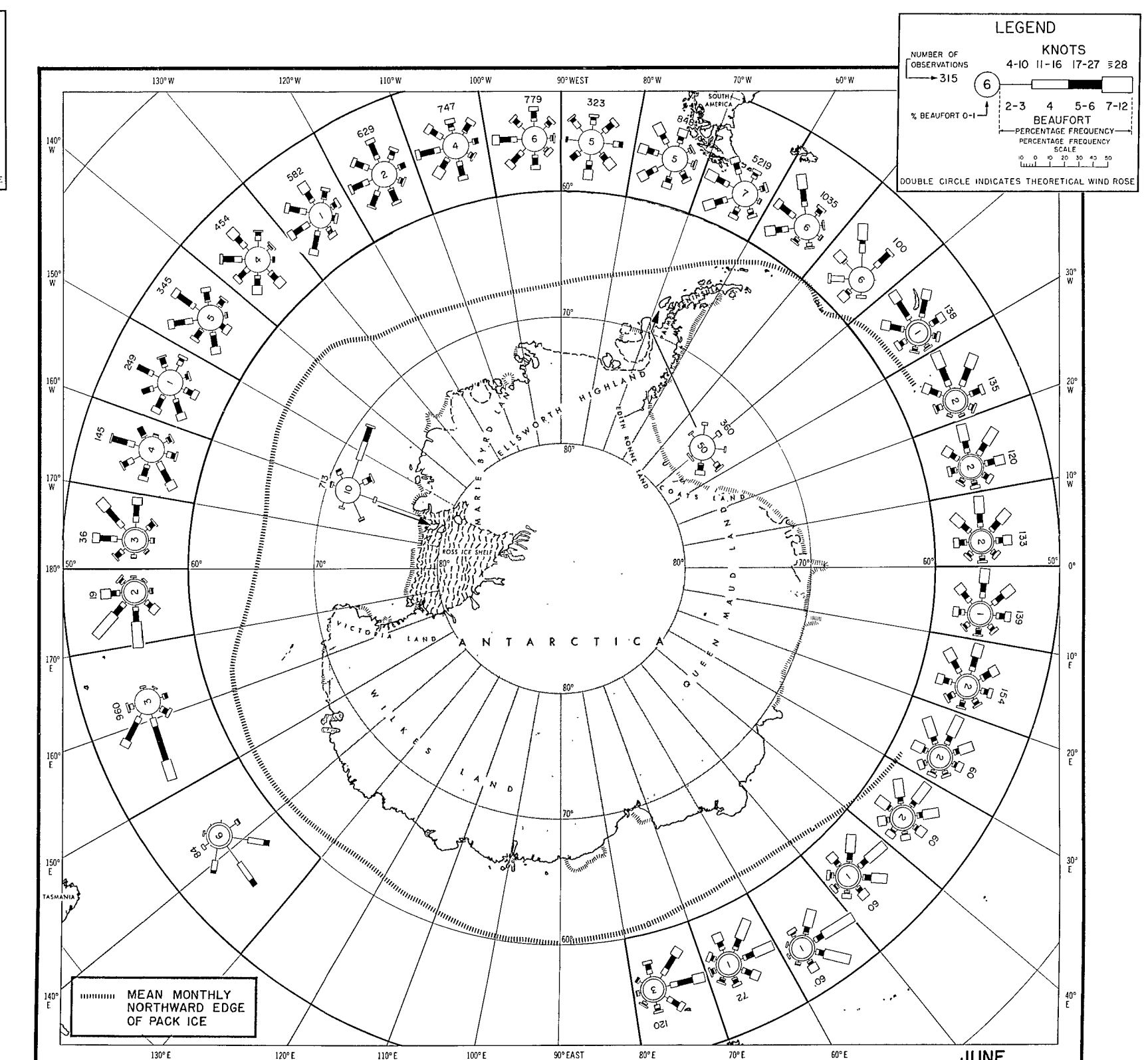
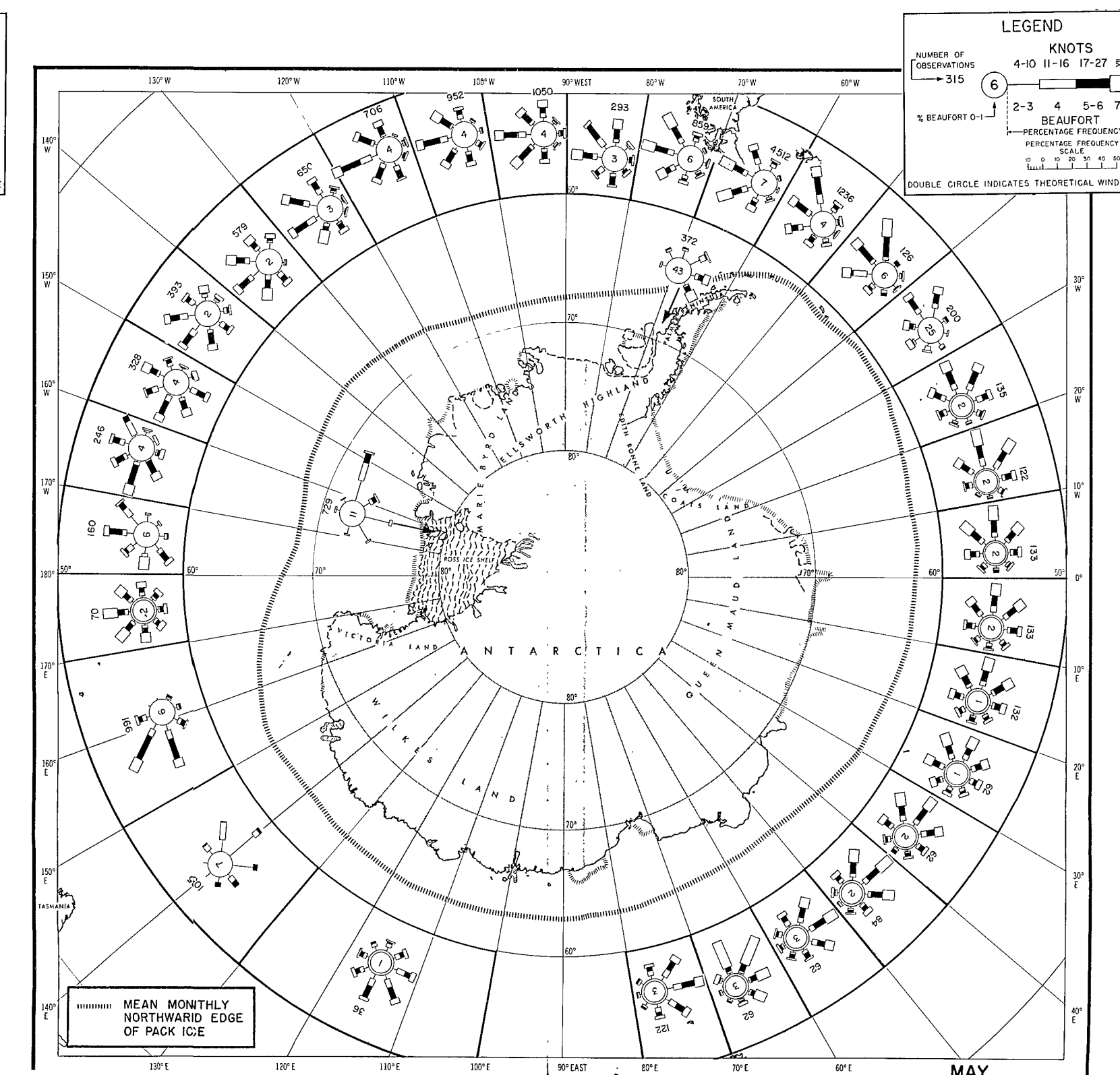
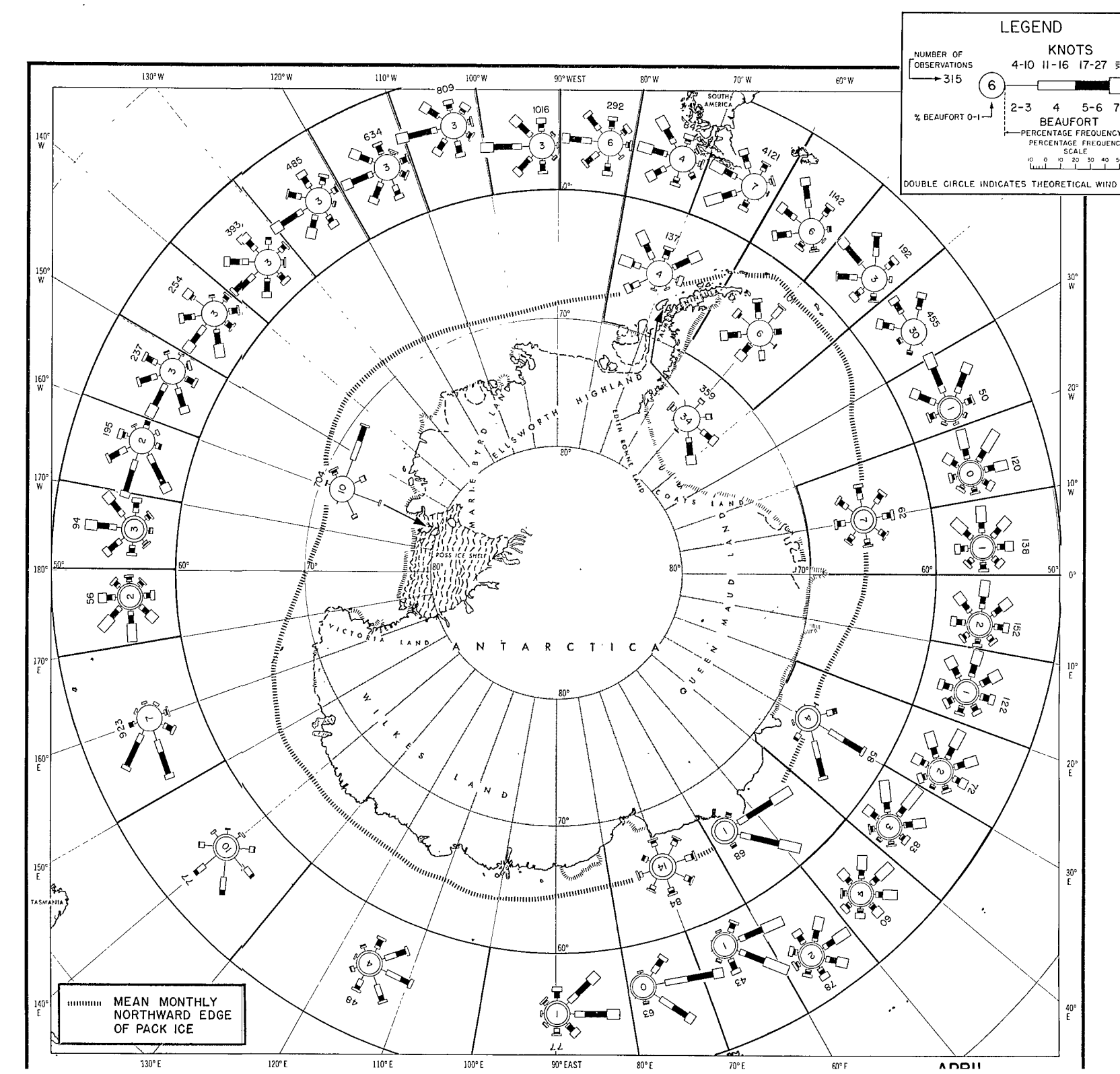
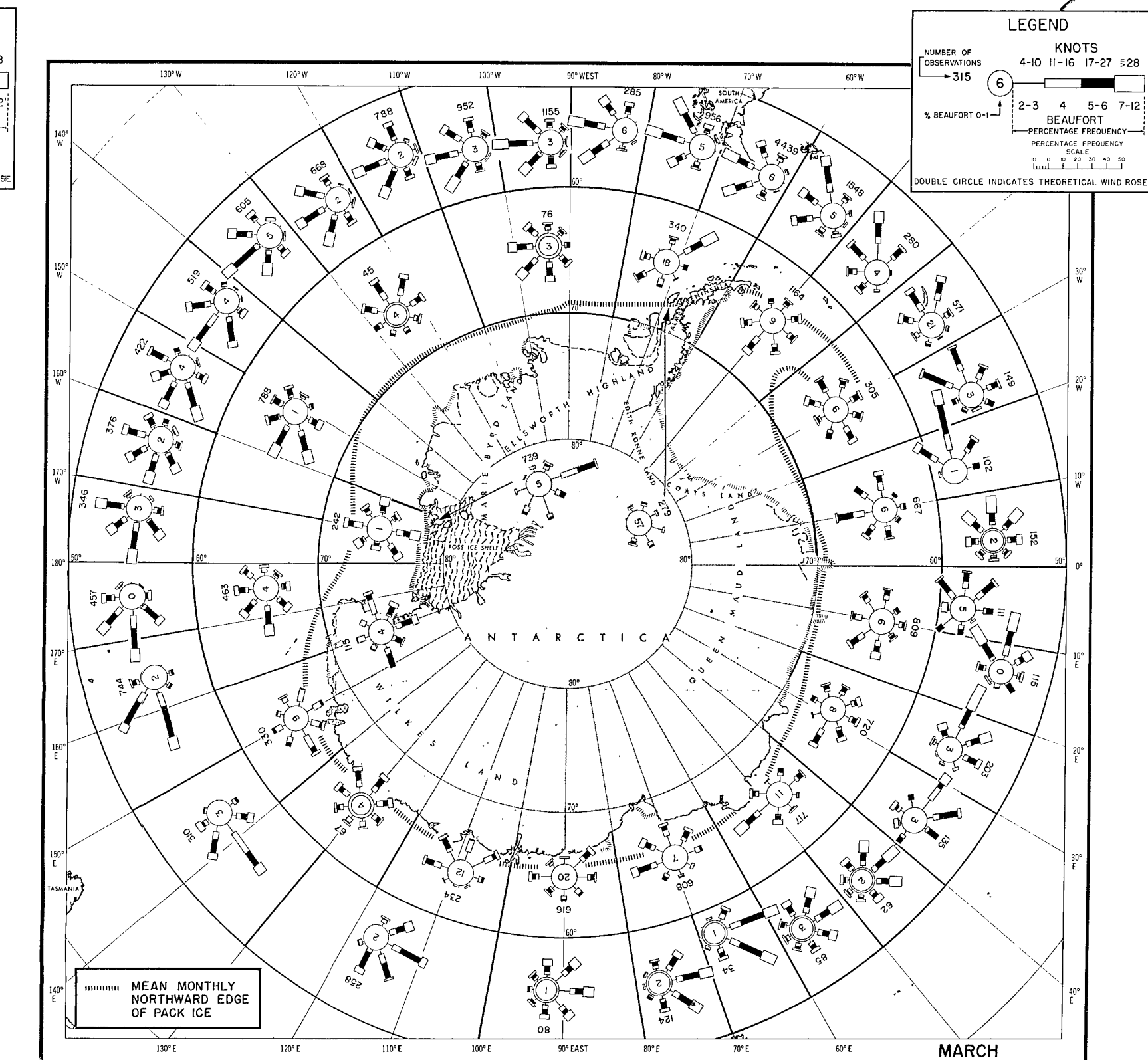
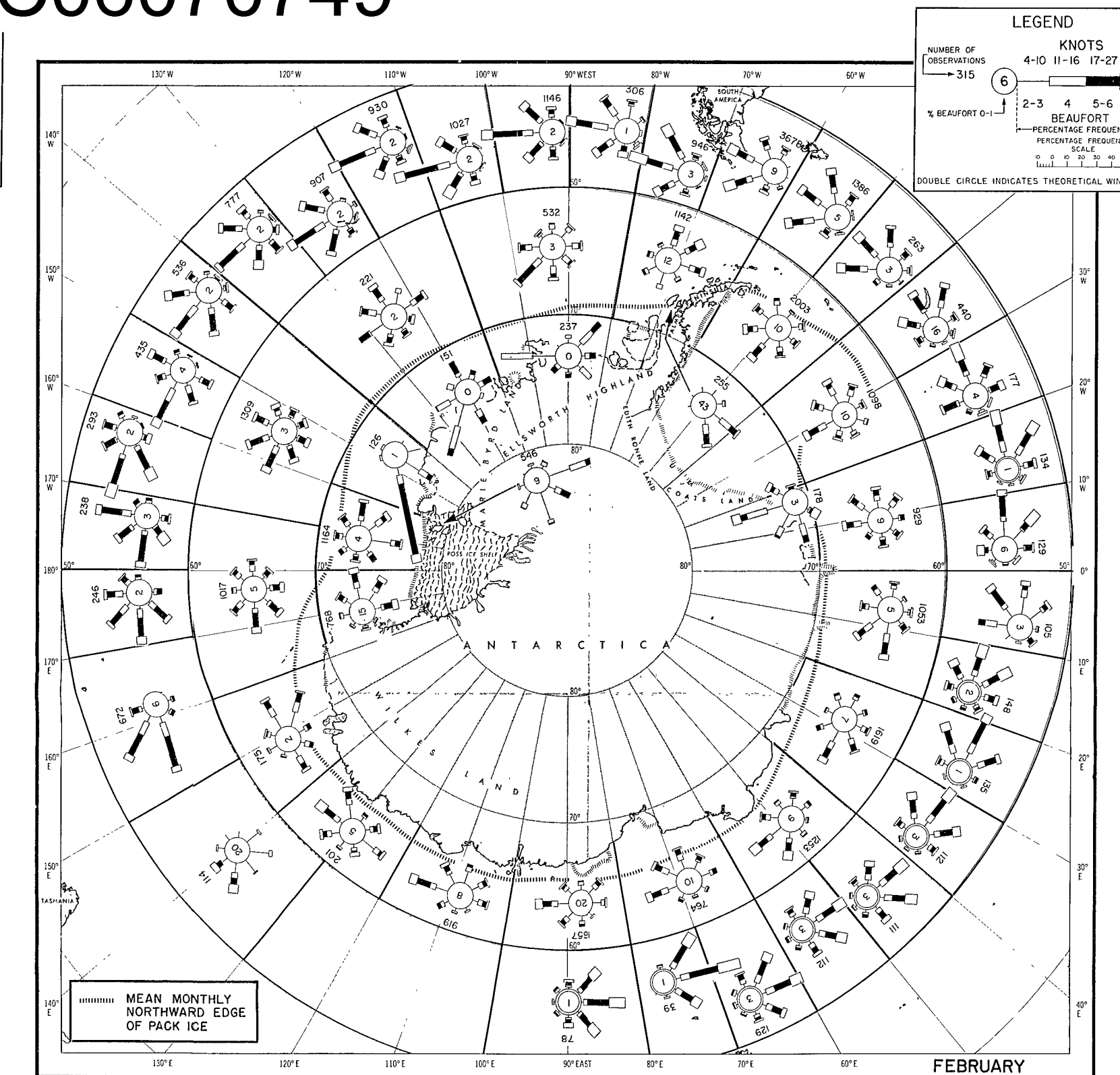
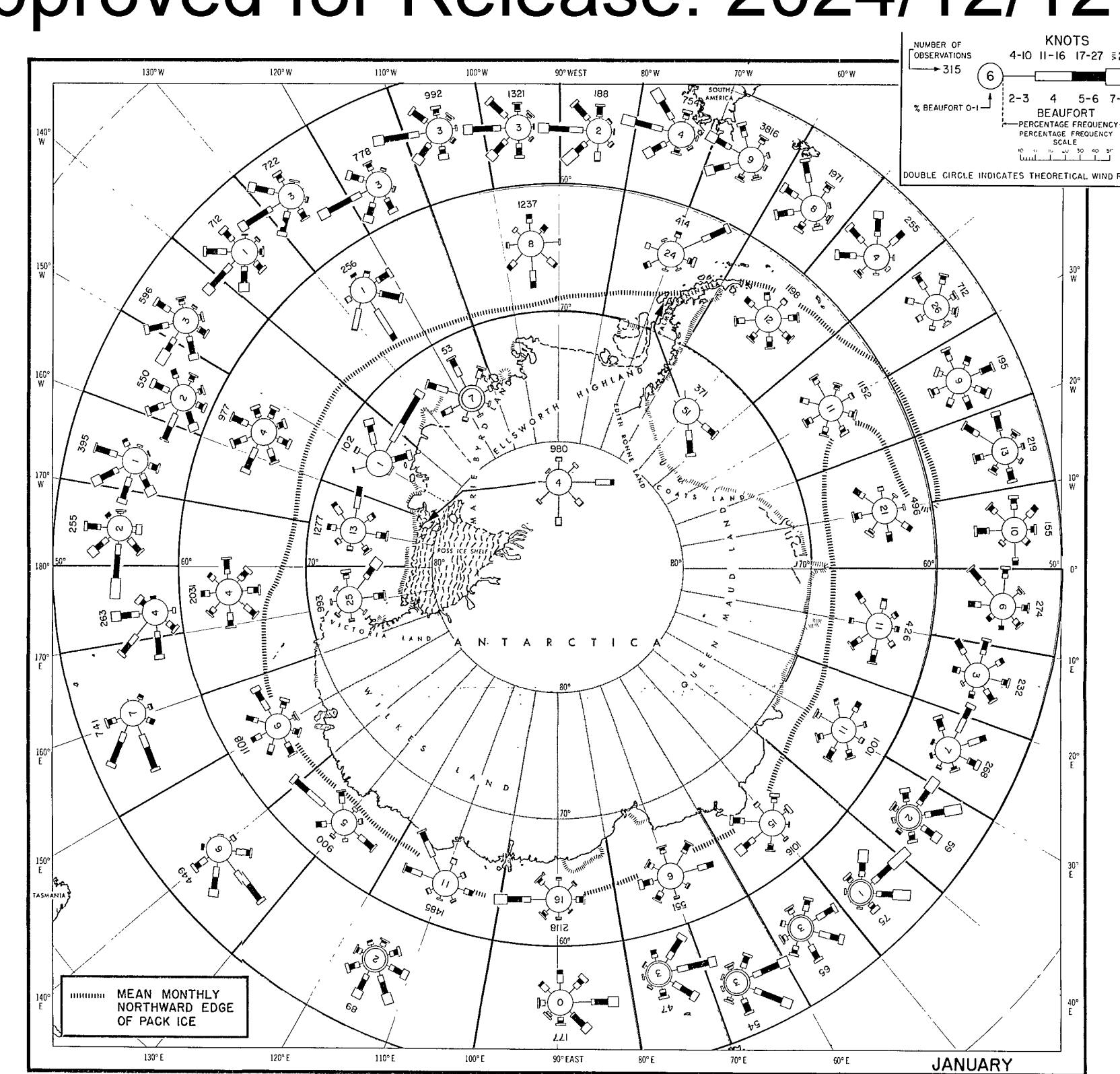
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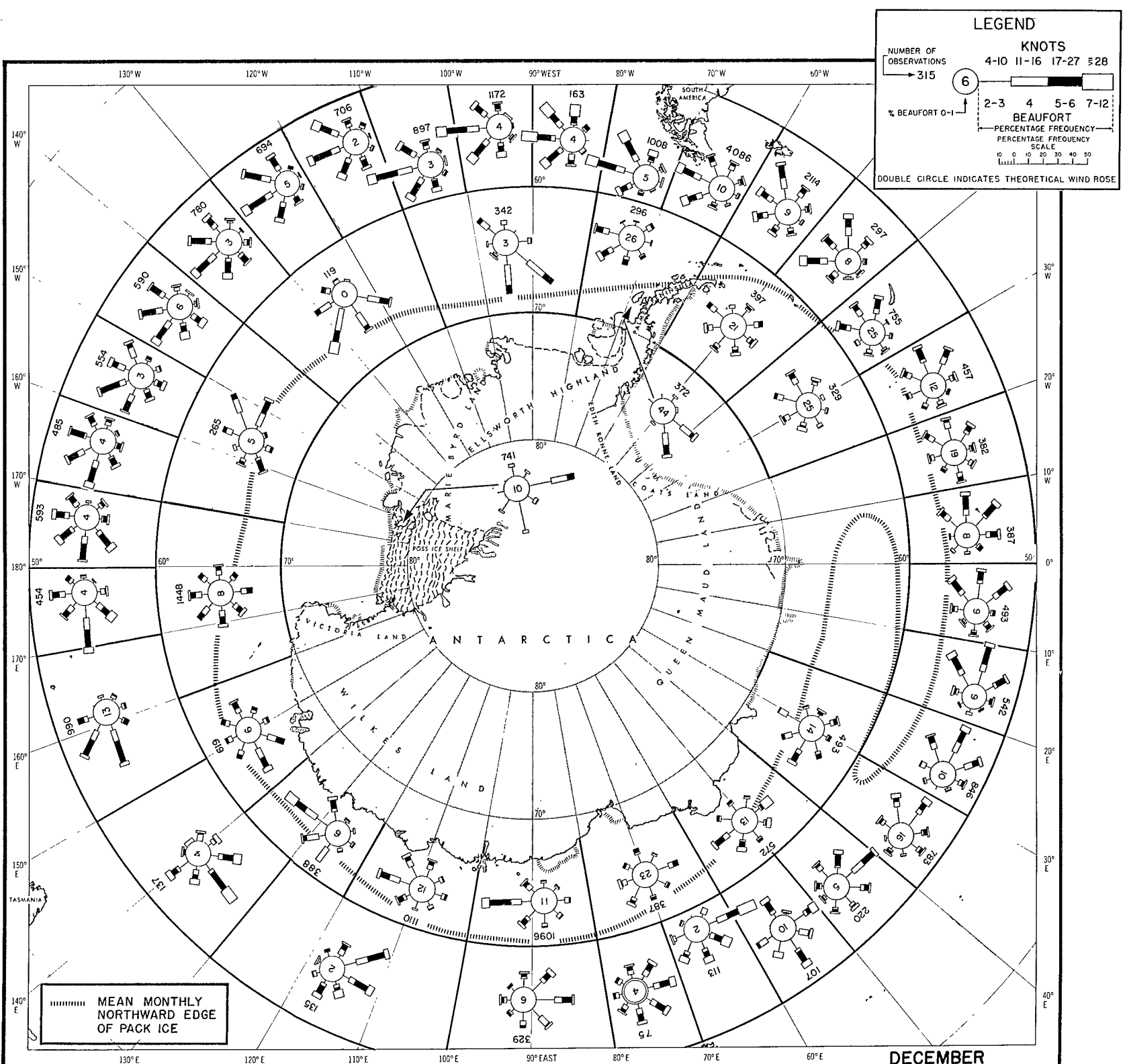
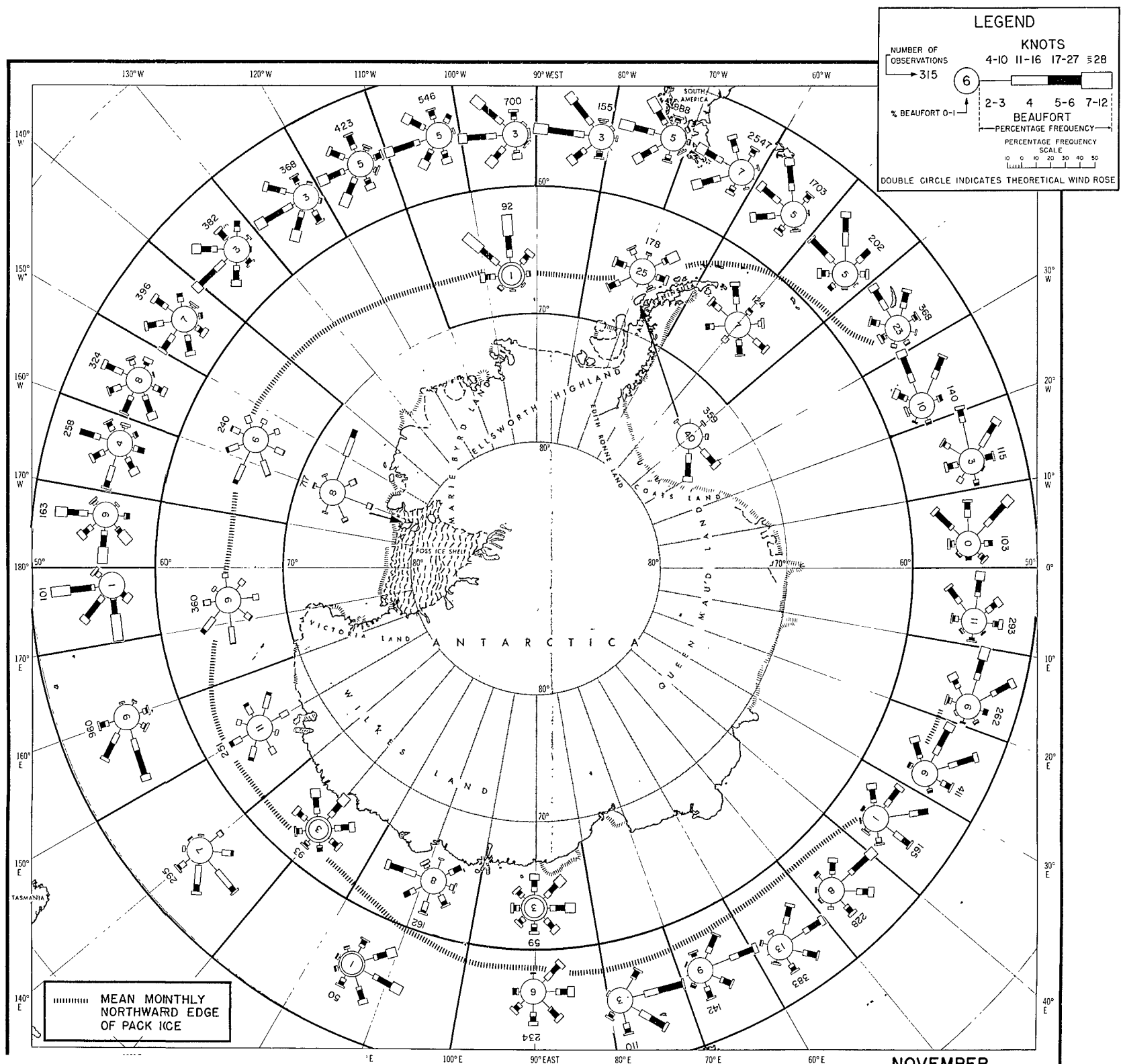
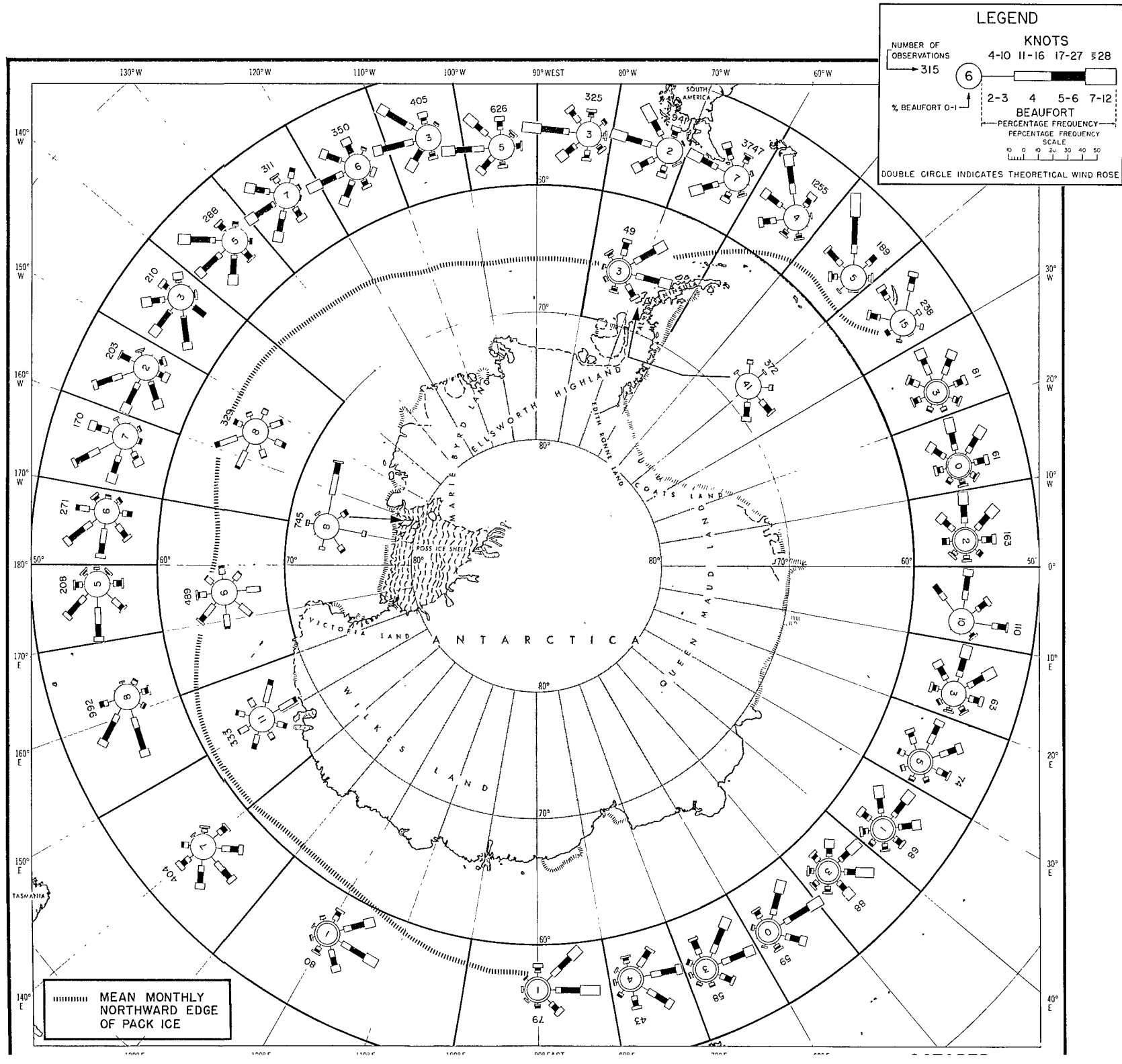
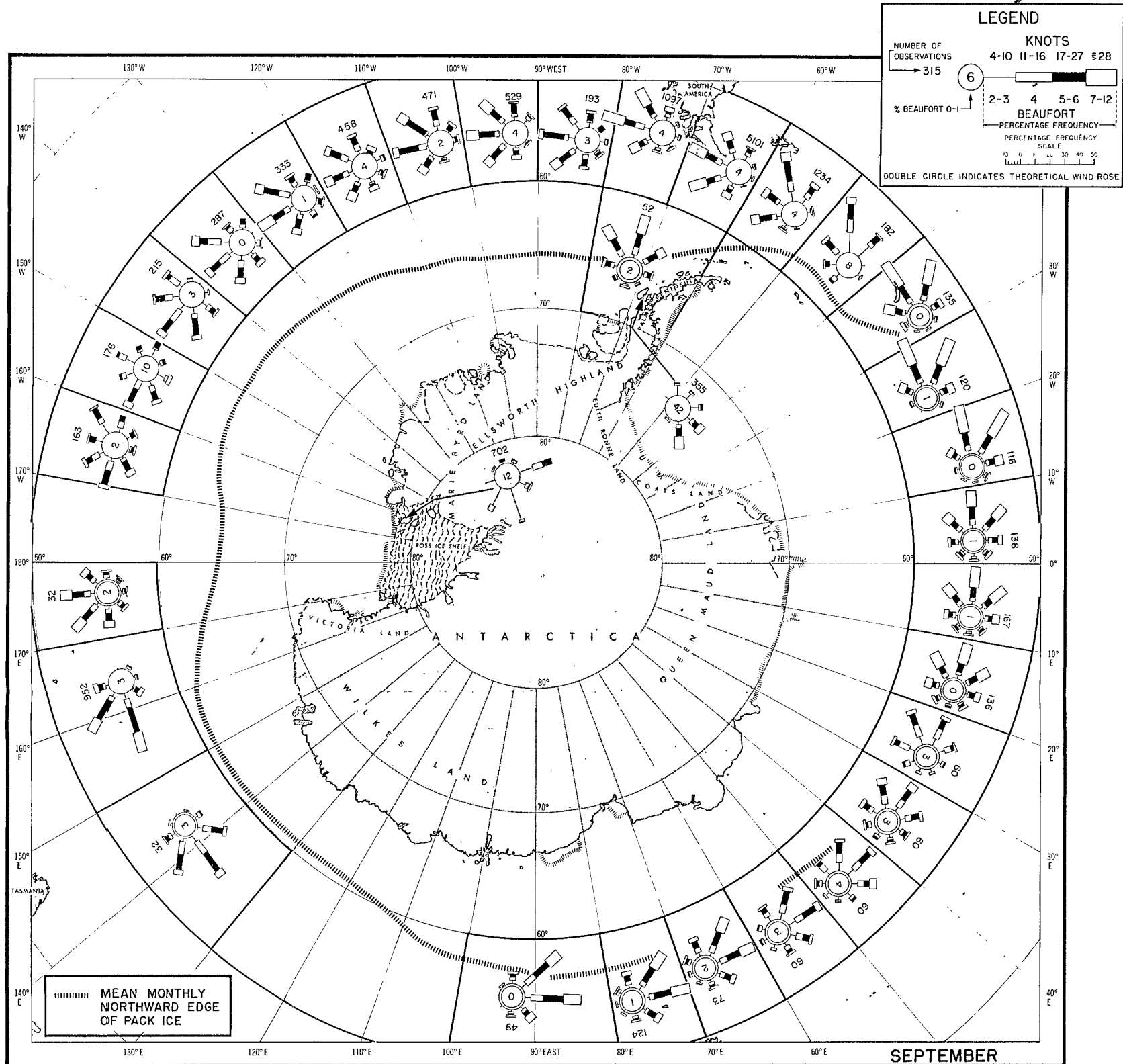
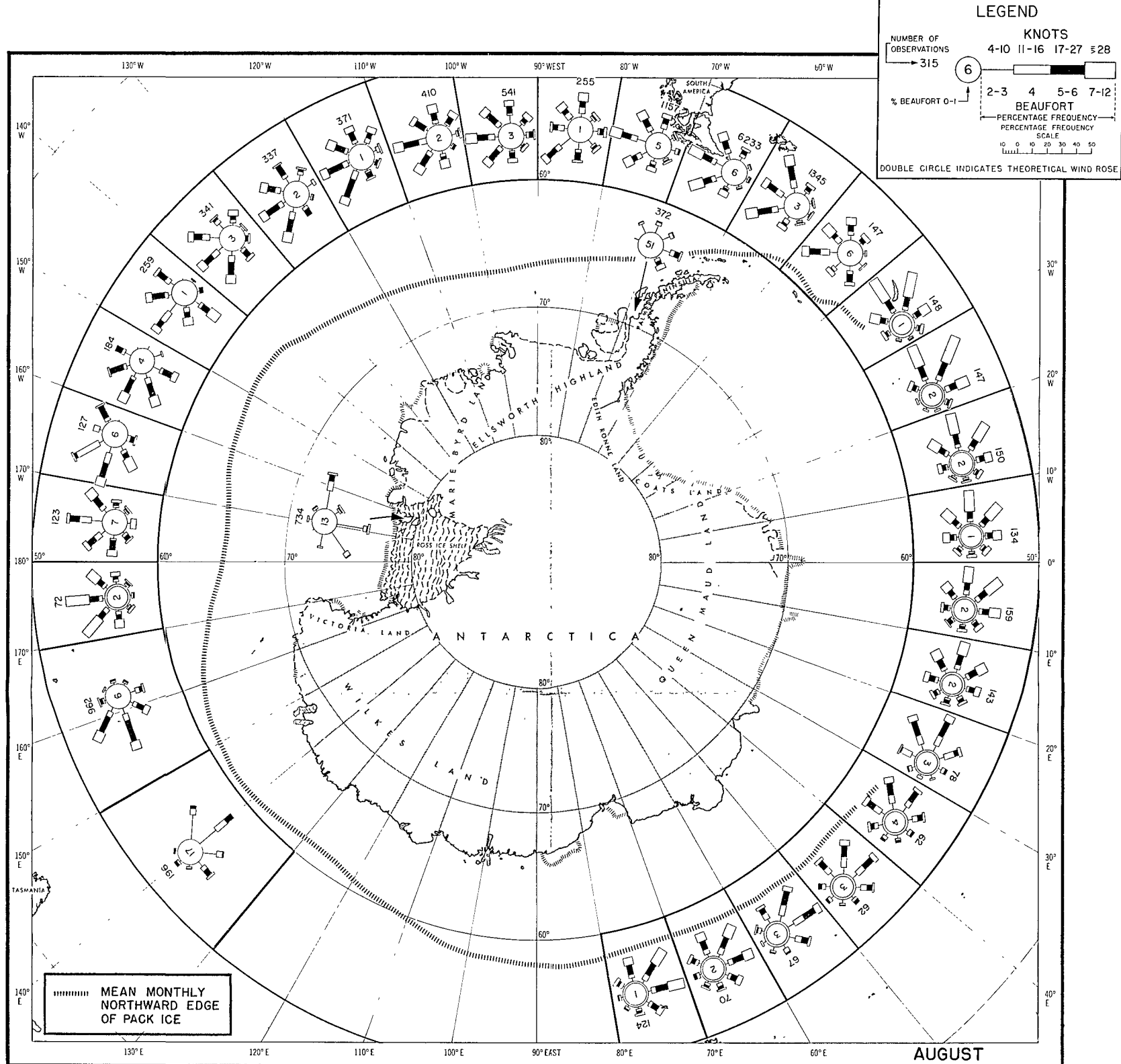
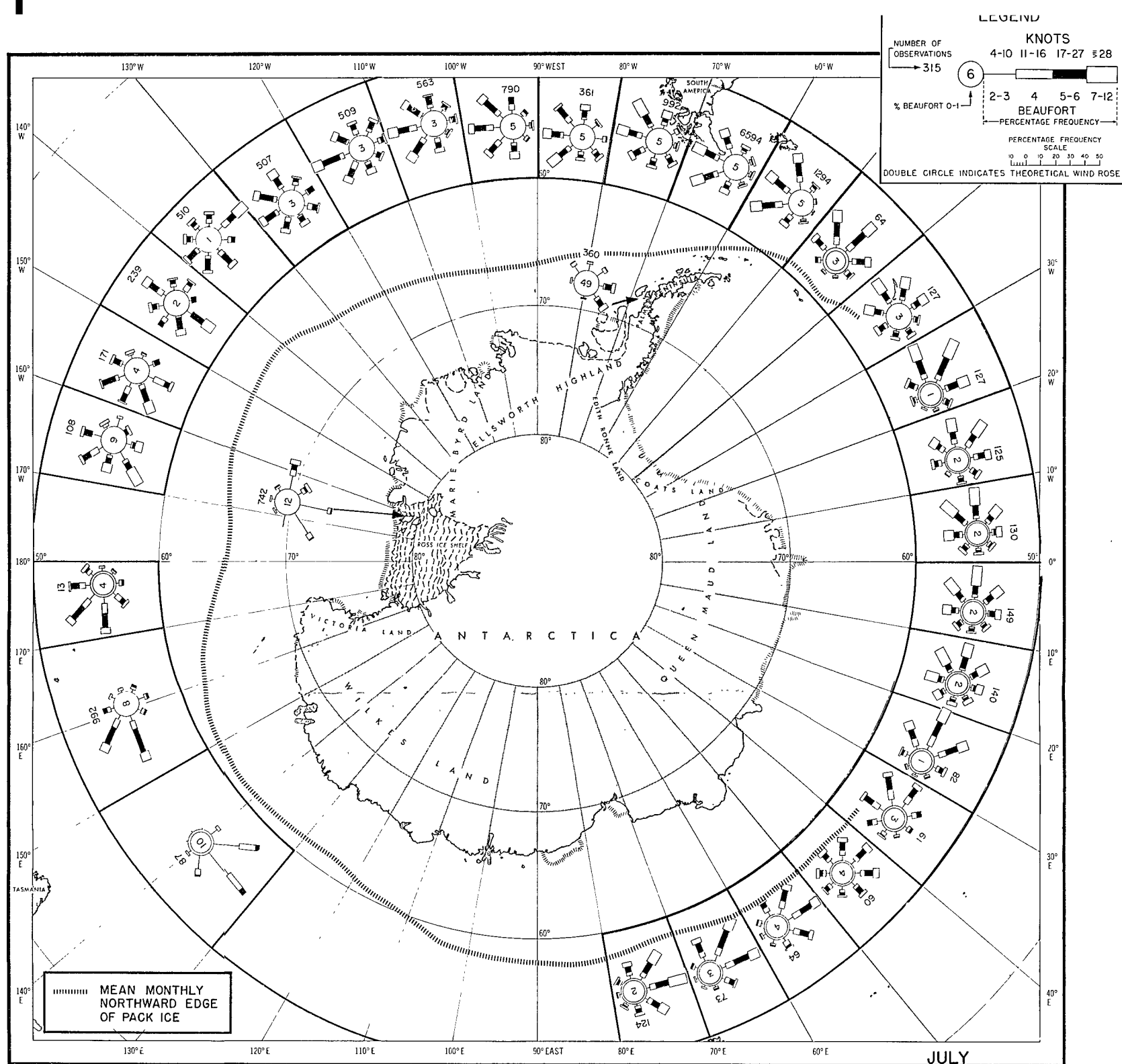
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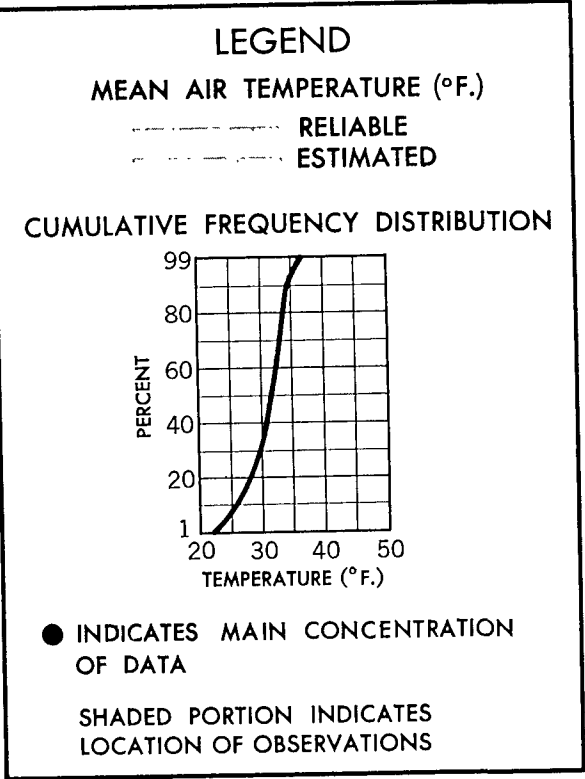
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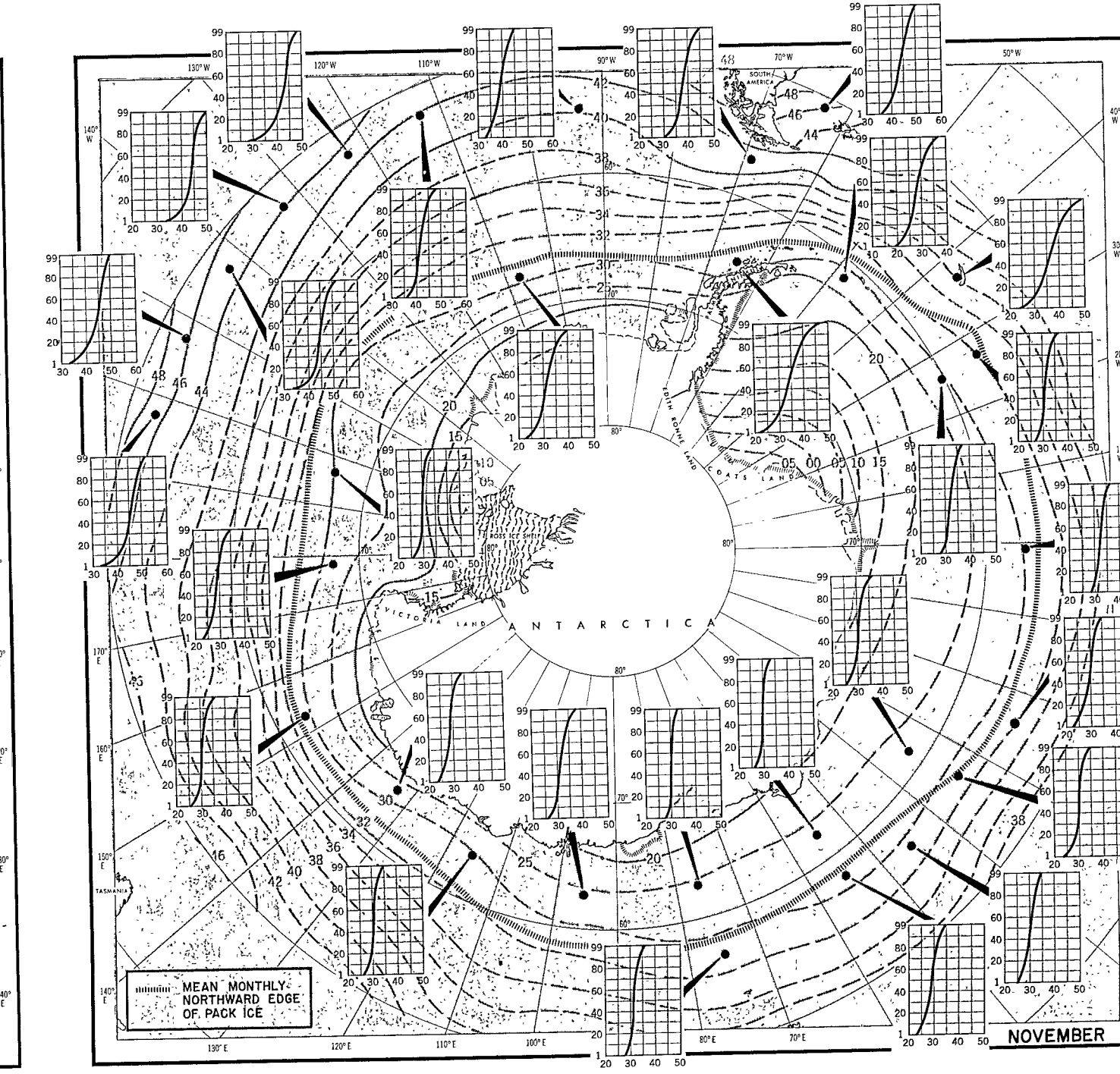
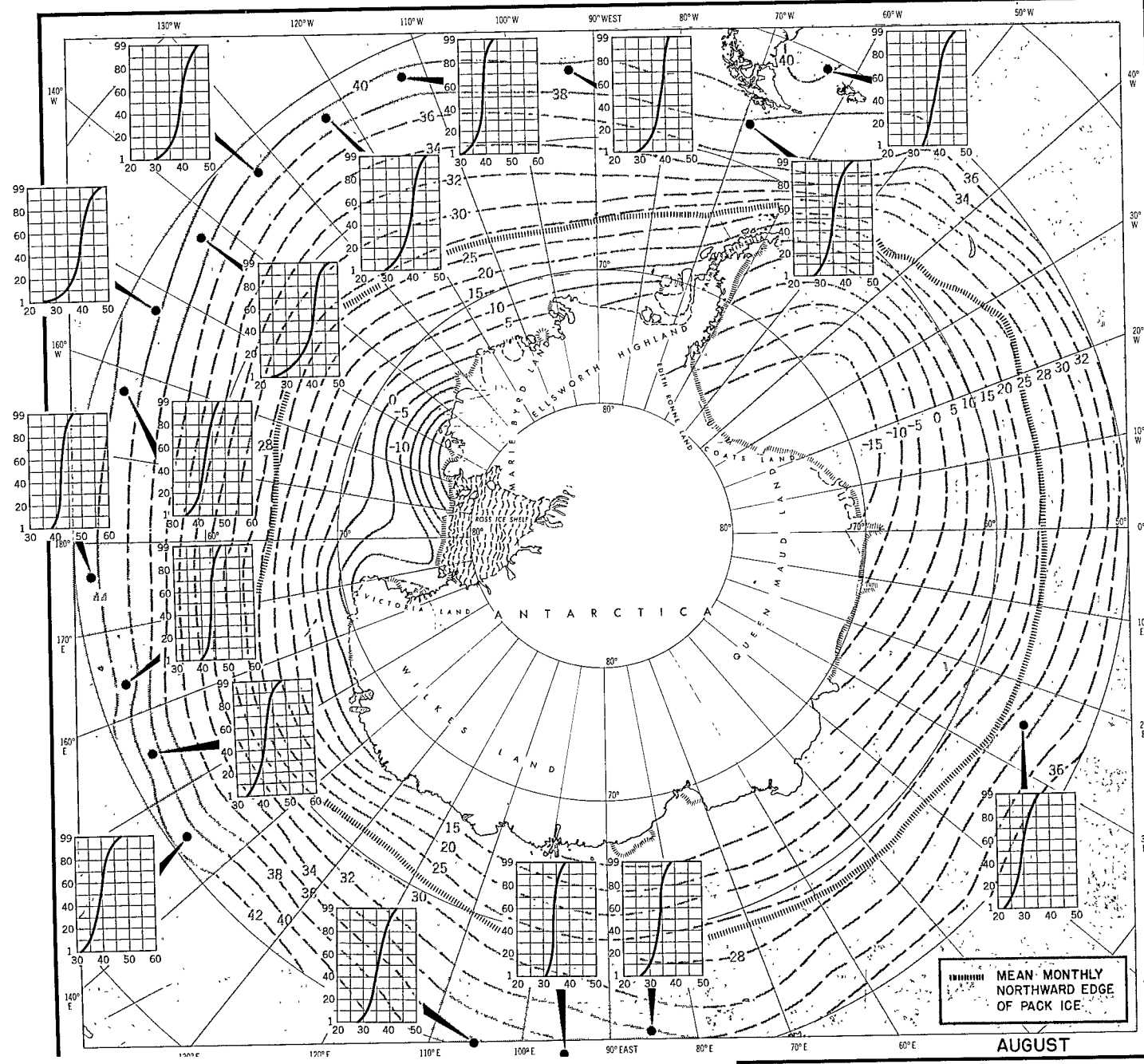
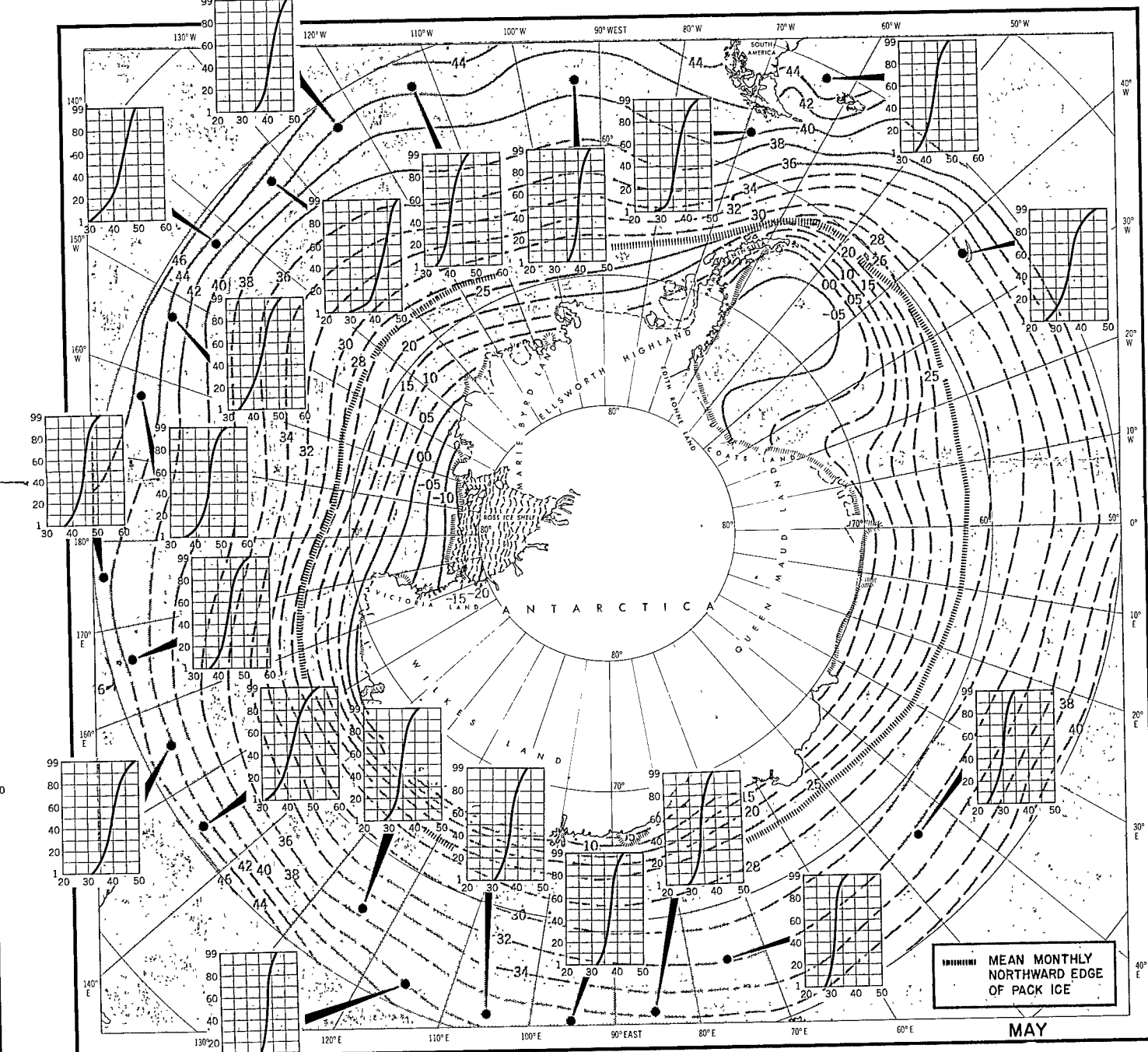
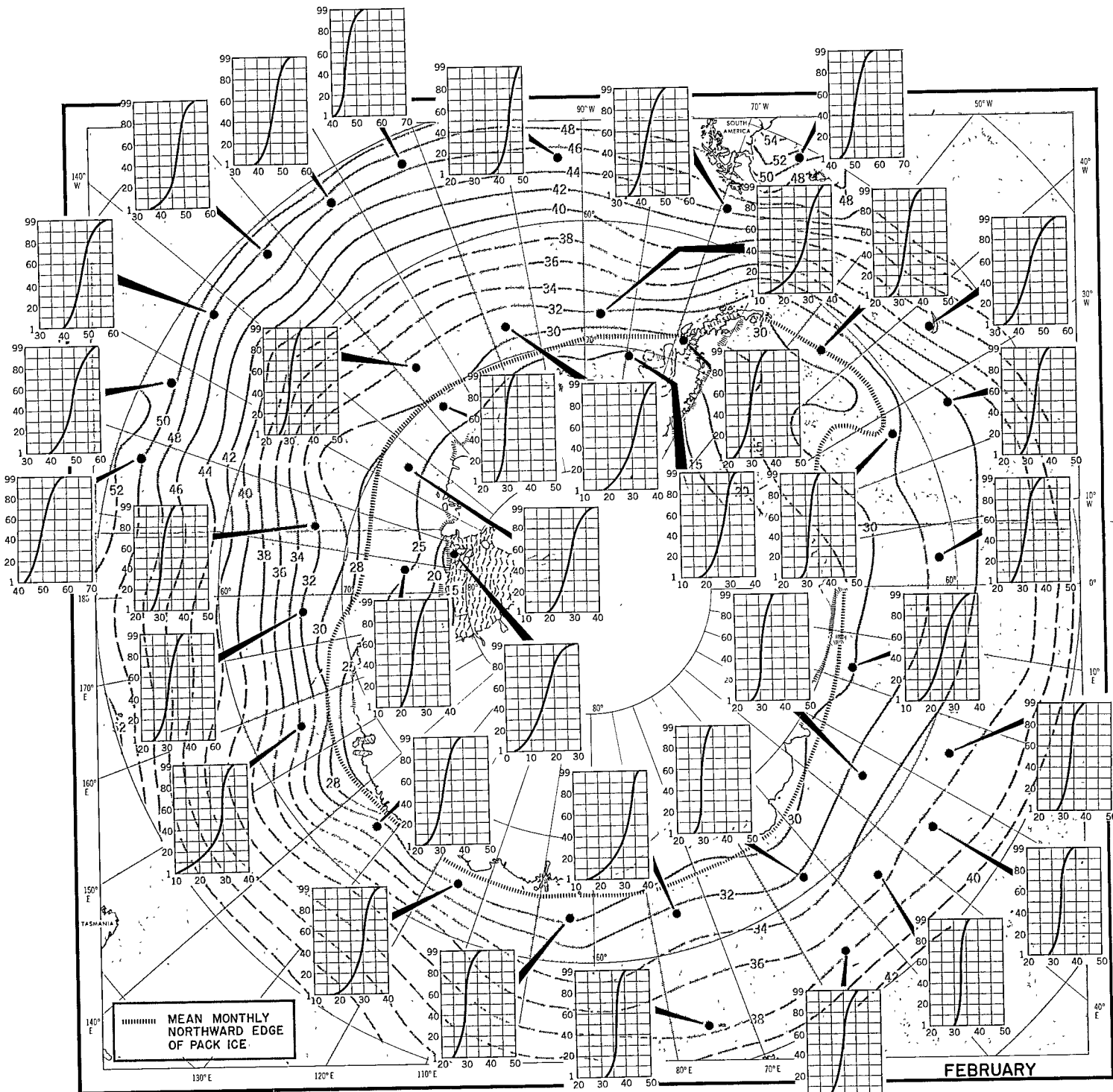
44. PETERSON, H. C. *Guide for Stonington Island Aviation Meteorology*. Ronne Antarctic Research Expedition, U.S. Office of Naval Research, Geophysics Branch, Physical Sciences Division, ONR Contract No. N6 onr 280. Washington. 1948. 25 p.
45. ROBERTS, P. W. "The Importance of Cold Weather Engineering in the Support of Arctic Operations." A thesis submitted in partial fulfillment of the requirements for the degree of Civil Engineer, Northwestern Technological Institute, 1954. 65 p. Unpublished.
46. RONNE ANTARCTIC RESEARCH EXPEDITION. *Antarctic Weather Statistics*. U.S. Office of Naval Research, Geophysics Branch, Physical Sciences Division, ONR Contract No. N6 onr 280, Washington. 1948. 42 p.
47. ROSCOE, J. H. "Contribution to the study of Antarctic surface features by photogeographical methods, *Antarctica*, vols. 1 and 2." Thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy to the Faculty of the Graduate School of the University of Maryland. 1952. 442 p. Unpublished.
48. RUBIN, M. J. "Seasonal Variations of the Antarctic Tropopause," *Journal of Meteorology*, vol. 10, no. 2, n. 127-134, 1953.
49. TREWARTHA, G. T. *An Introduction to Climate*. Ed 3. New York: McGraw-Hill. 1954. 402 p.
50. UNION OF SOUTH AFRICA, WEATHER BUREAU, DEPARTMENT OF TRANSPORT. "Mean Sea-Level Pressure," *NOTOS*, vol. 1, nos. 1 and 3, 1952; vol. 2, nos. 1, 2, and 3, 1953; and vol. 3, no. 1, 1954.
51. ———. *Synoptic Charts for the Southern Hemisphere, 1951, 1952, and 1953*. Pretoria. Film. Unpublished.
52. U.S., DEPARTMENT OF THE AIR FORCE. "Antarctica," *Regional Photo Interpretation Series*. Washington. 1953. 171 p.
53. U.S., DEPARTMENT OF THE ARMY, OFFICE OF THE QUARTERMASTER GENERAL. *Clothing Almanac No. 4*. Washington. 1950. 18 p.
54. U.S., DEPARTMENT OF THE ARMY. *Basic Arctic Manual*. Department of the Army Field Manual FM 31-70. February, 1951. 188 p.
55. U.S., HYDROGRAPHIC OFFICE. *Sailing Directions for Antarctica Including the Off-Lying Islands South of Latitude 60°*. Hydrographic Office Publication No. 138. Washington. 1943. 312 p.
56. ———. "Climatological Data for Marsden Squares 480 thru 551." Tabulated by the U.S. Weather Bureau from Weather Bureau Decks: 115 (U.S. Merchant Marine Deck, 1941-1948), 116 (U.S. Merchant Marine Deck, 1949-1953), 192 (Hamburg, Deutsche Seewart Deck), 193 (Nederlands, Meteorologisch Instituut Deck), 194 (Great Britain, Meteorological Office Deck), and 195 (U.S. Navy Ships' Logs Observations Deck). Unpublished.
57. U.S., NAVAL PHOTOGRAPHIC INTERPRETATION CENTER. *Antarctic Bibliography*. Washington. 1951. 147 p.
58. U.S., NAVY, ANTARCTIC DEVELOPMENT PROJECT. "Weather Processes from the Ross Sea Westward to the Greenwich Meridian," *Report of Operation Highjump, Aerology*. No. 4, p. 35-45. 1947.
59. U.S., NAVY, CHIEF OF NAVAL OPERATIONS, FLIGHT SERVICE SECTION AEROLOGY. *Aerological Aspects of Second Antarctic Development Project, 1947-1948*. NAVAER 50-45T-10. Washington. 1948. 24 p.
60. ———. *Aerological Observations and Summaries for the Antarctic from 15 December 1946 to 15 March 1947; a Project of Operation Highjump, Task Force 68*. NAVAER 50-1R-214. Washington. 1948. 404 p.
61. U.S., NAVY, CIVIL ENGINEER CORPS. *Cold Weather Engineering*. Washington. 1948-1949. 109 p.
62. U.S., NAVY, OFFICE OF THE CHIEF OF NAVAL OPERATIONS, COORDINATING COMMITTEE. *Naval Arctic Operations Handbook; Operational Notes*. Pt. 2, p. 227-484. Washington. 1950.
63. ———. *Naval Arctic Operations Handbook; General Information*. Pt. 1, p. 1-225, Washington. 1949.
64. U.S., WEATHER BUREAU. *Manual of Radiosonde Observations (WBAN)*. Circular P, ed. 6. 1950. 184 p.
65. U.S., WEATHER BUREAU, NATIONAL WEATHER RECORDS CENTER. "Mean Upper Air Values for Stations South of 30°S." Job No. 6010, ser. 6742, September 30, 1955. Unpublished.
66. ———. "Upper Air Wind Frequencies for Stations South of 30°S." Job No. 6010, ser. 6742, October 1, 1955. Unpublished.
67. VOWINCKEL, F., AND OOSTHUIZEN, C. M. "Weather Types and Weather Elements Over the Antarctic Ocean During the Whaling Season," *NOTOS*, vol. 2, no. 3, p. 157-168, 1953.
68. WILSON, E. A., AND OTHERS. "Meteorology; Observations at Winter Quarters and on Sledge Journeys," *National Antarctic Expedition, 1901-1904*. Pt. 1, p. 1-548, 1908.

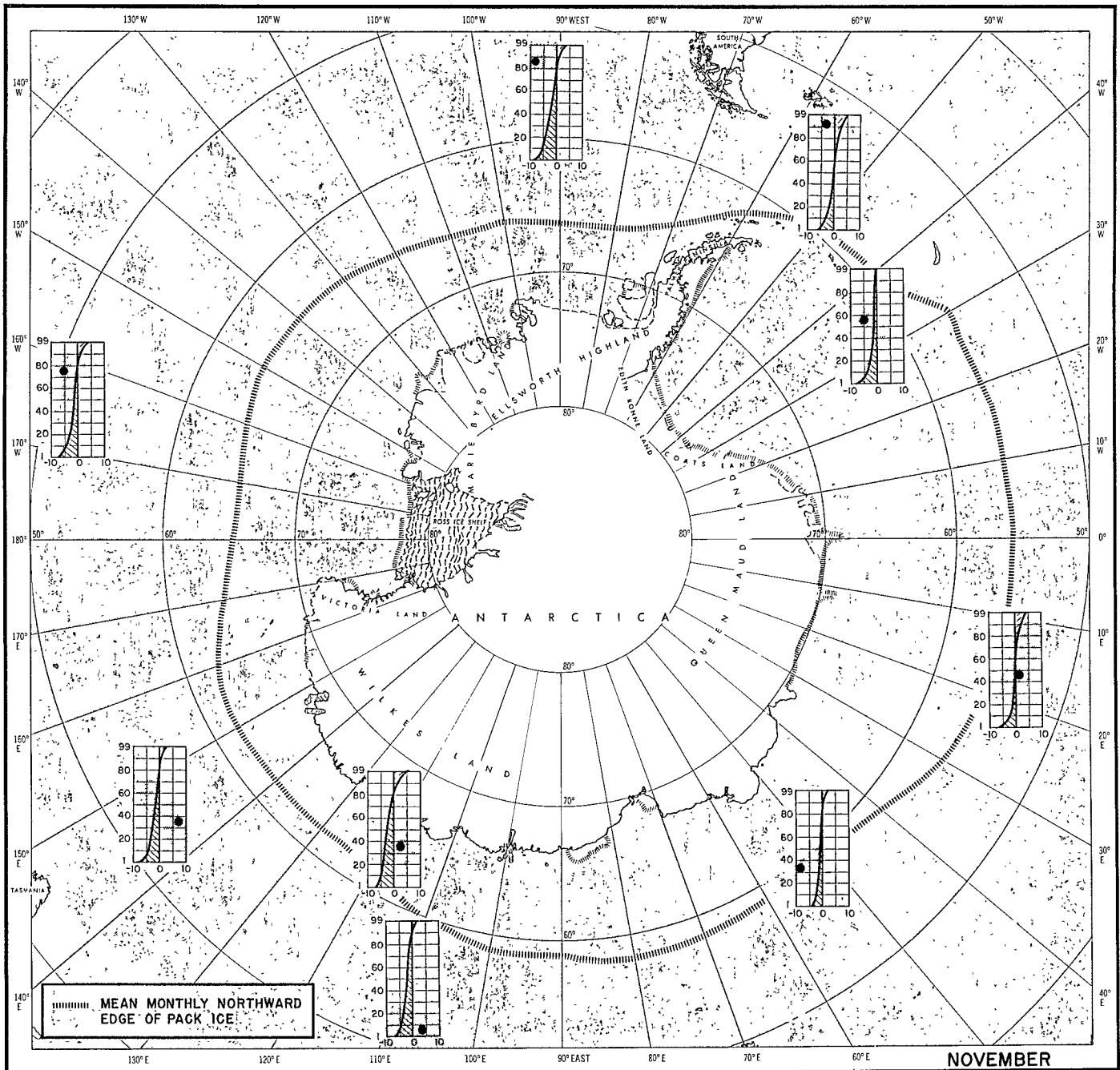
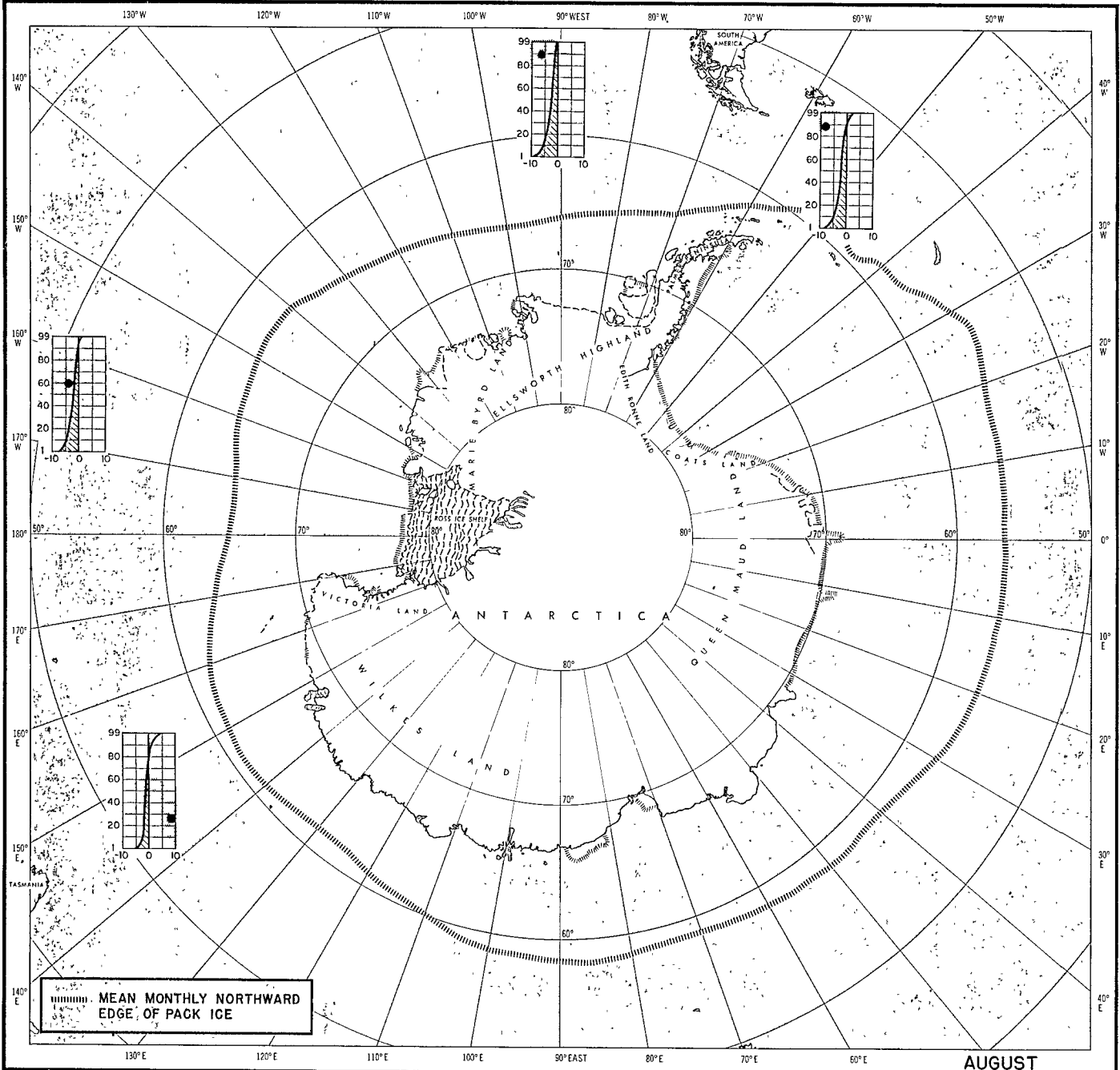
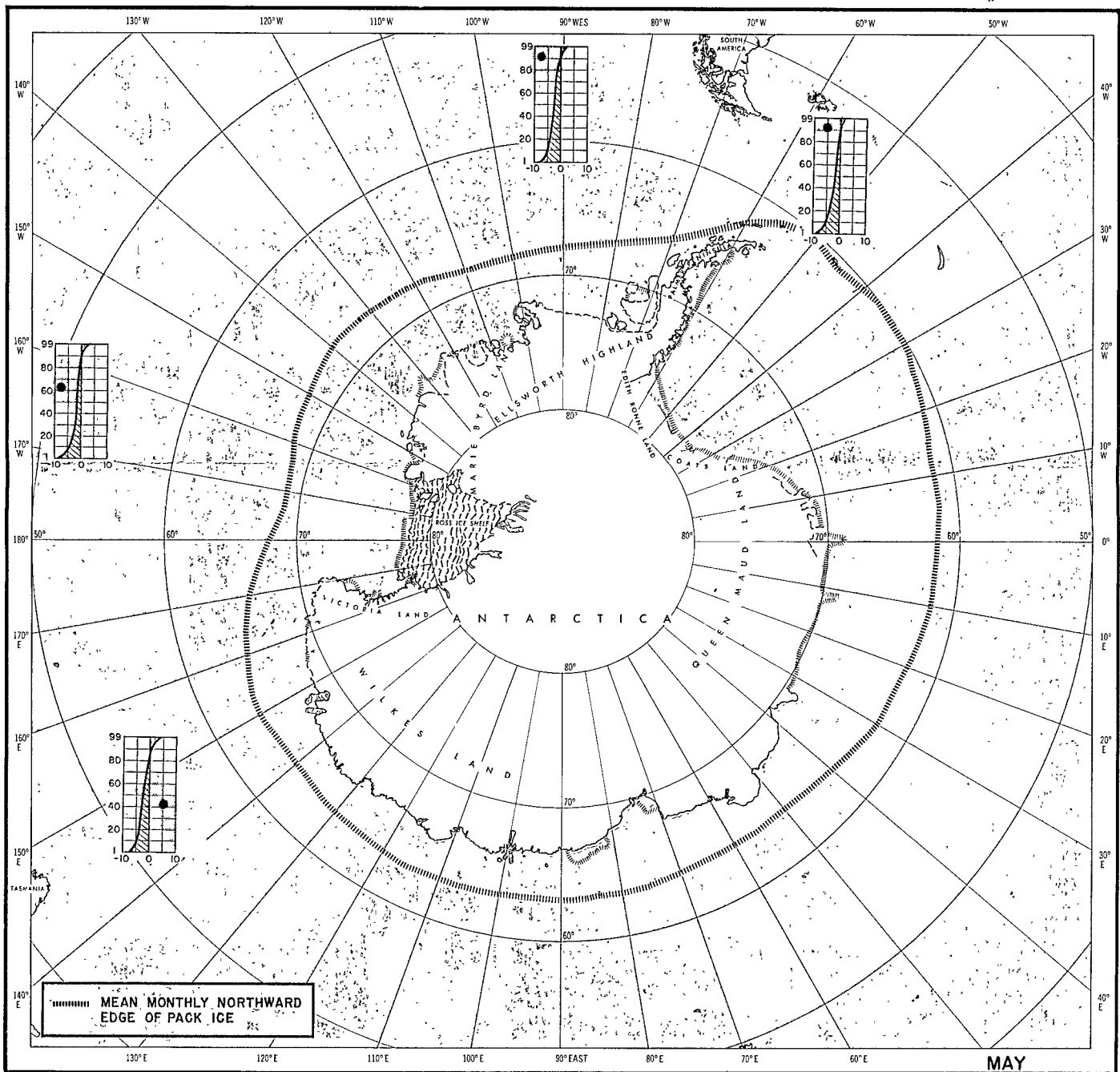
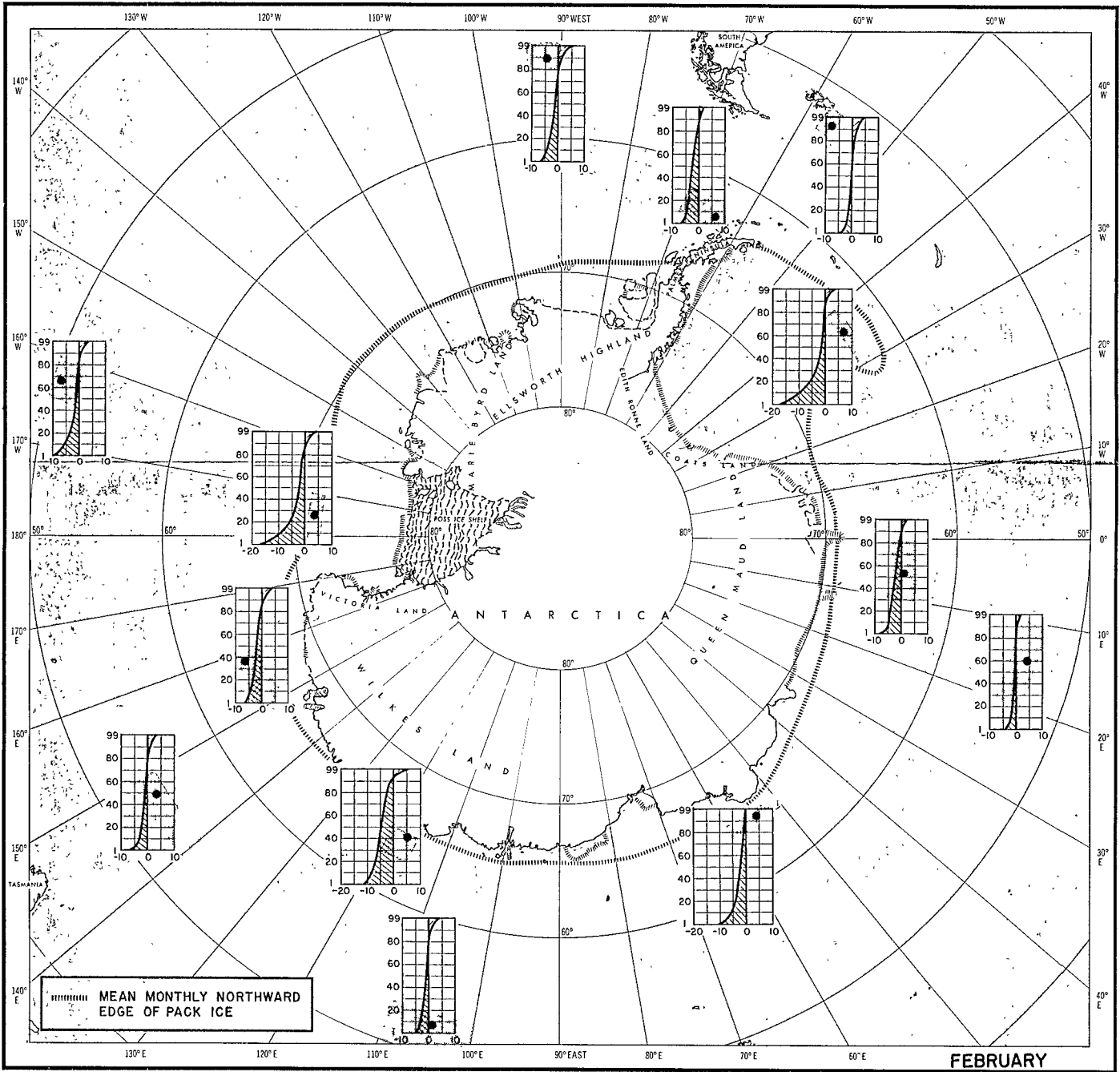
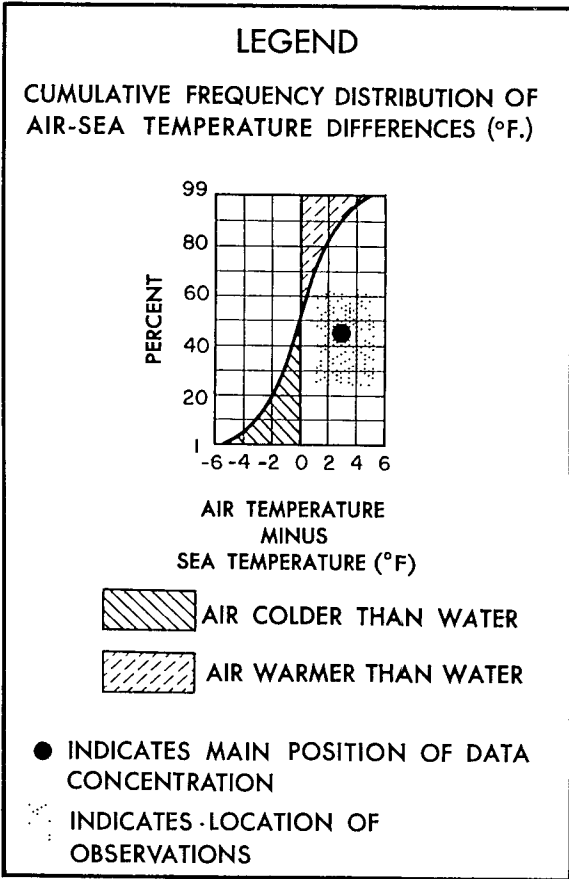




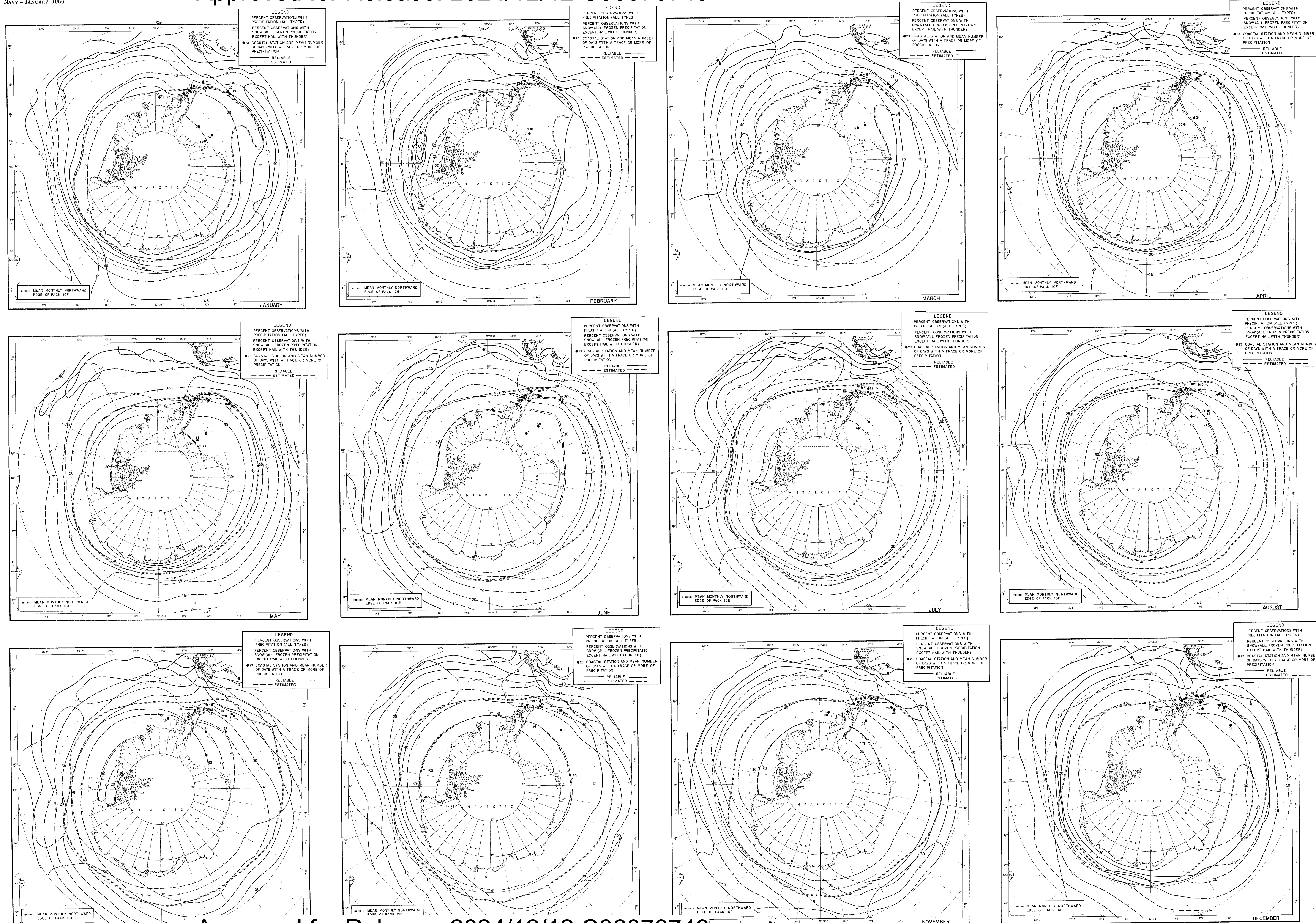


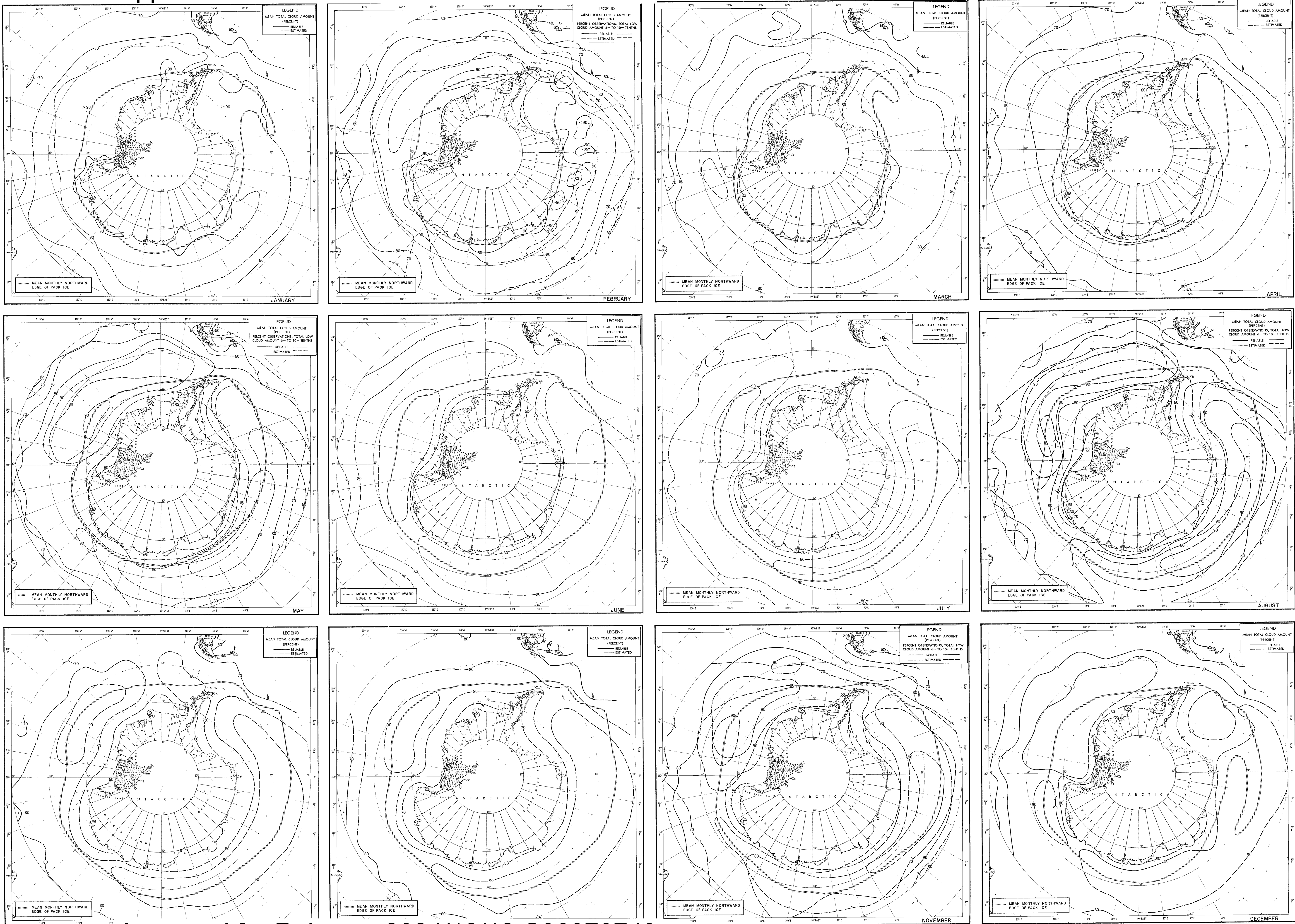
MEAN AIR TEMPERATURE (°F.) AND CUMULATIVE FREQUENCY DISTRIBUTION, FEBRUARY, MAY, AUGUST, AND NOVEMBER



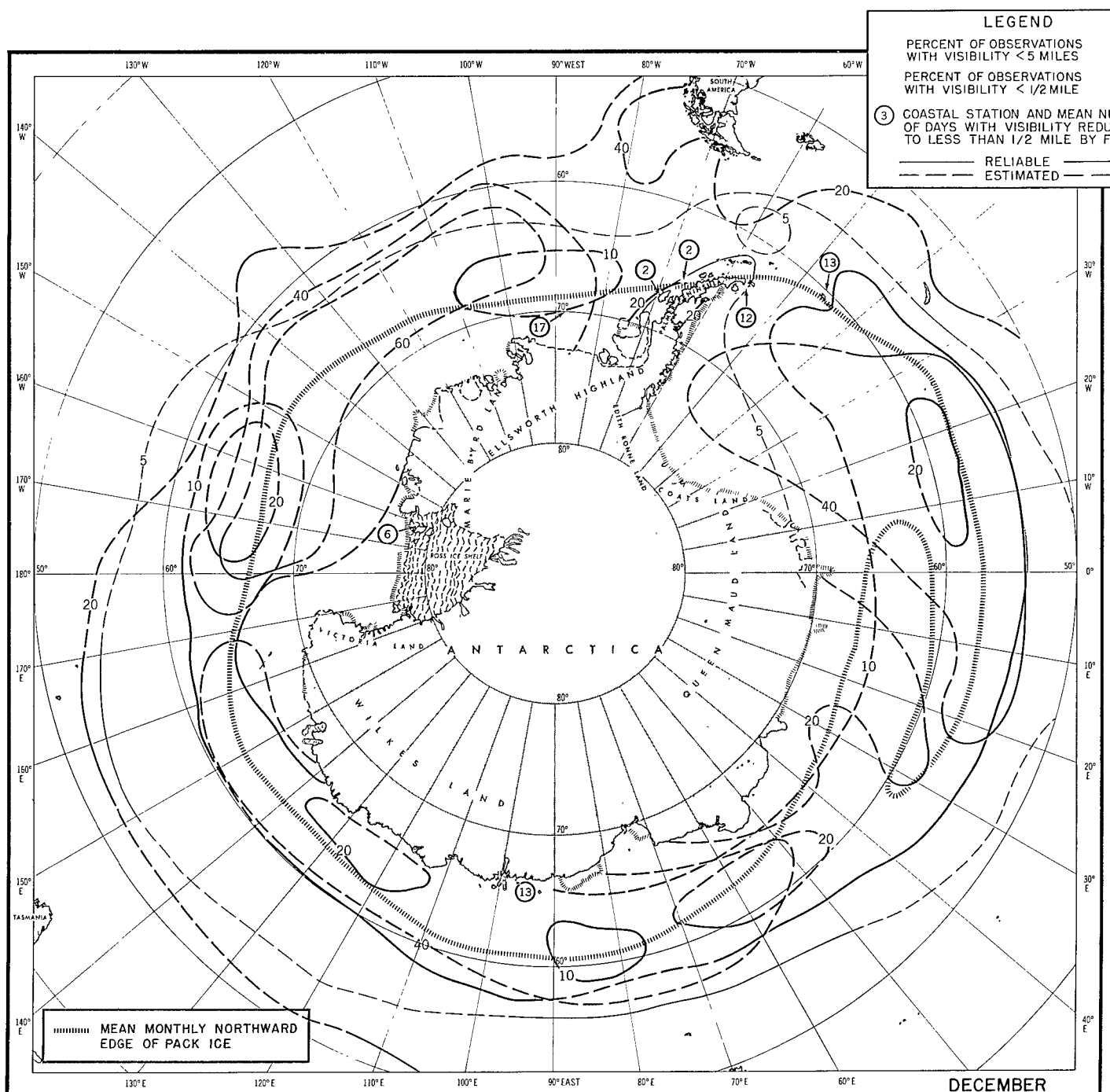
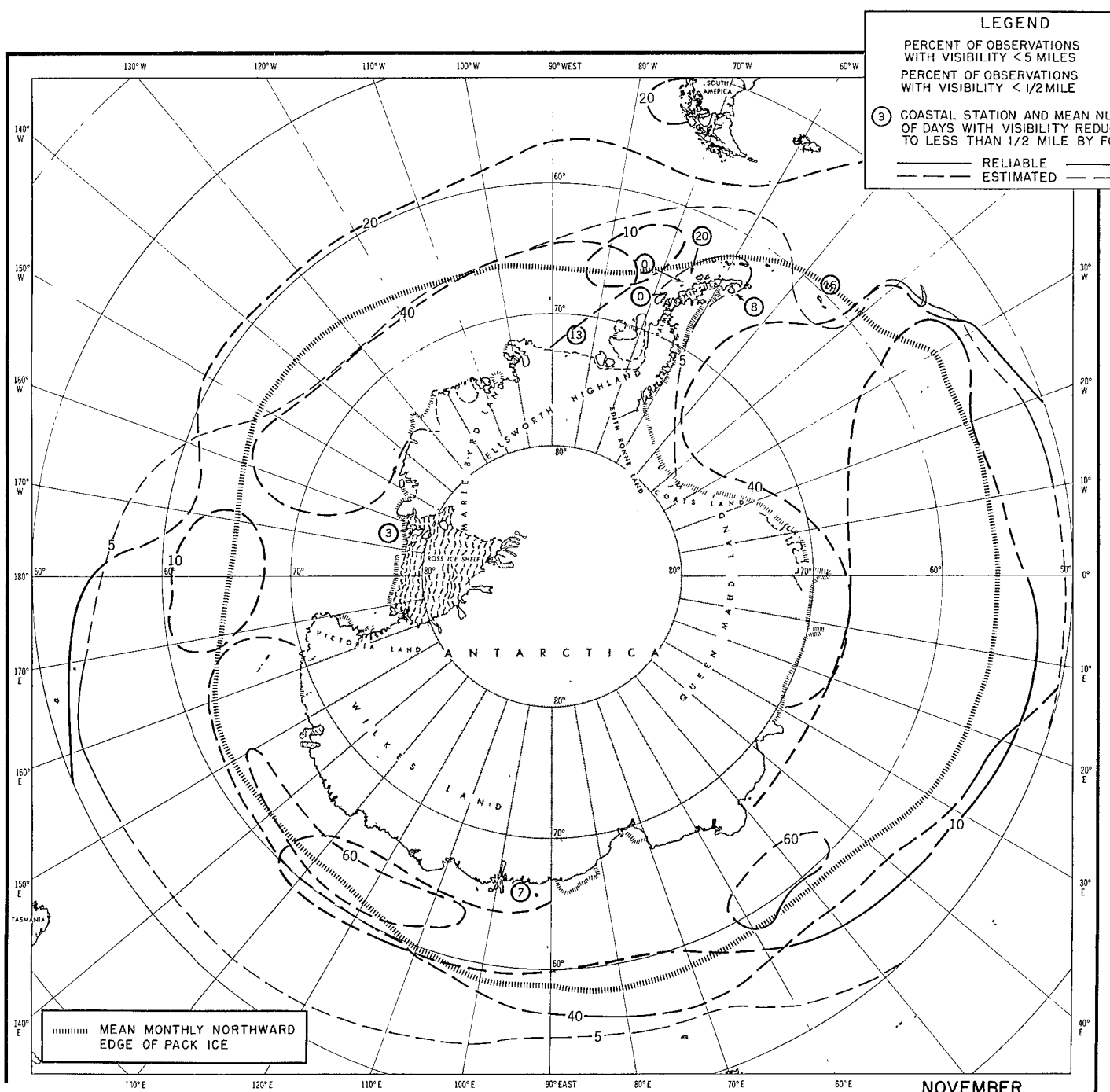
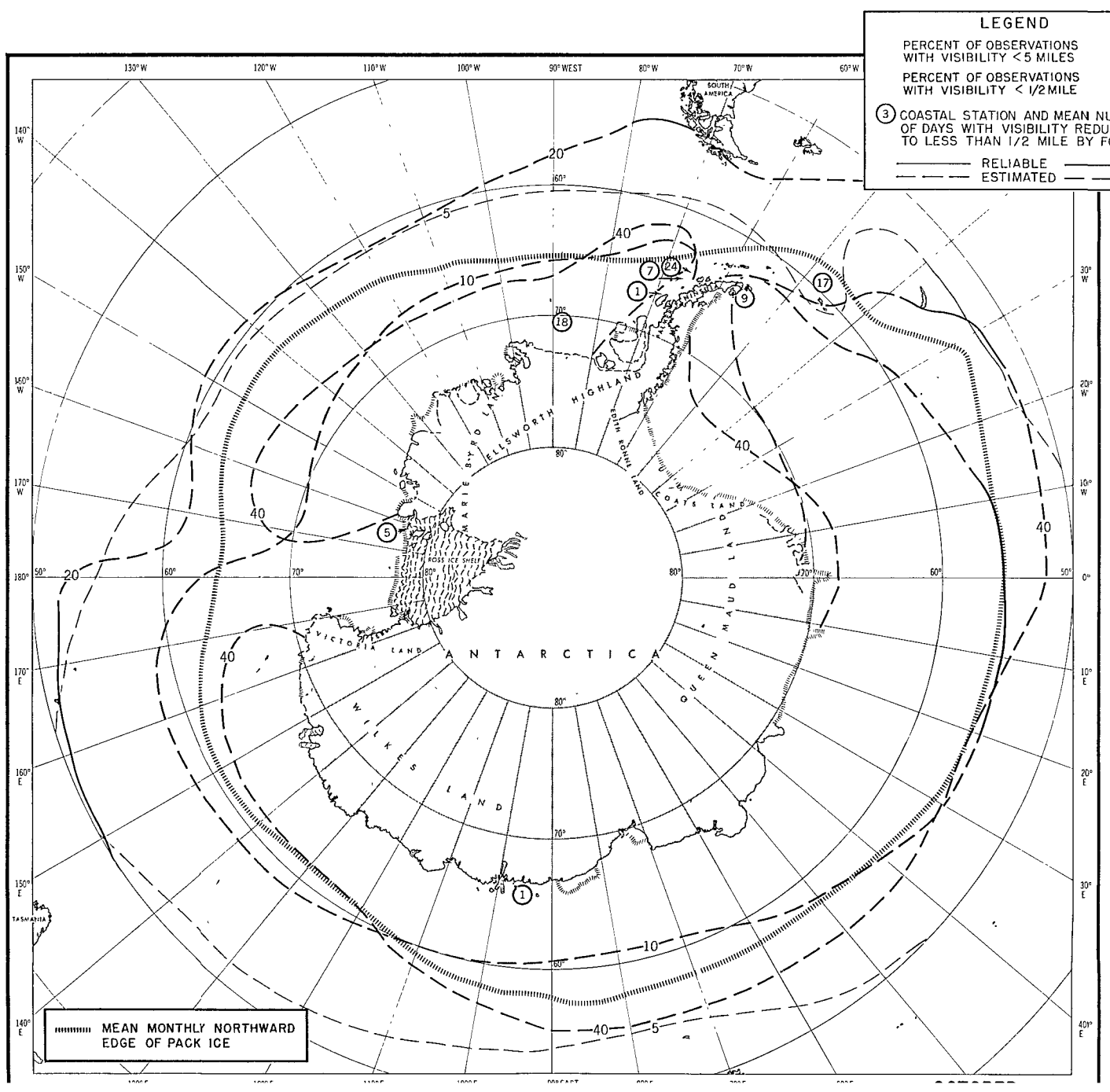
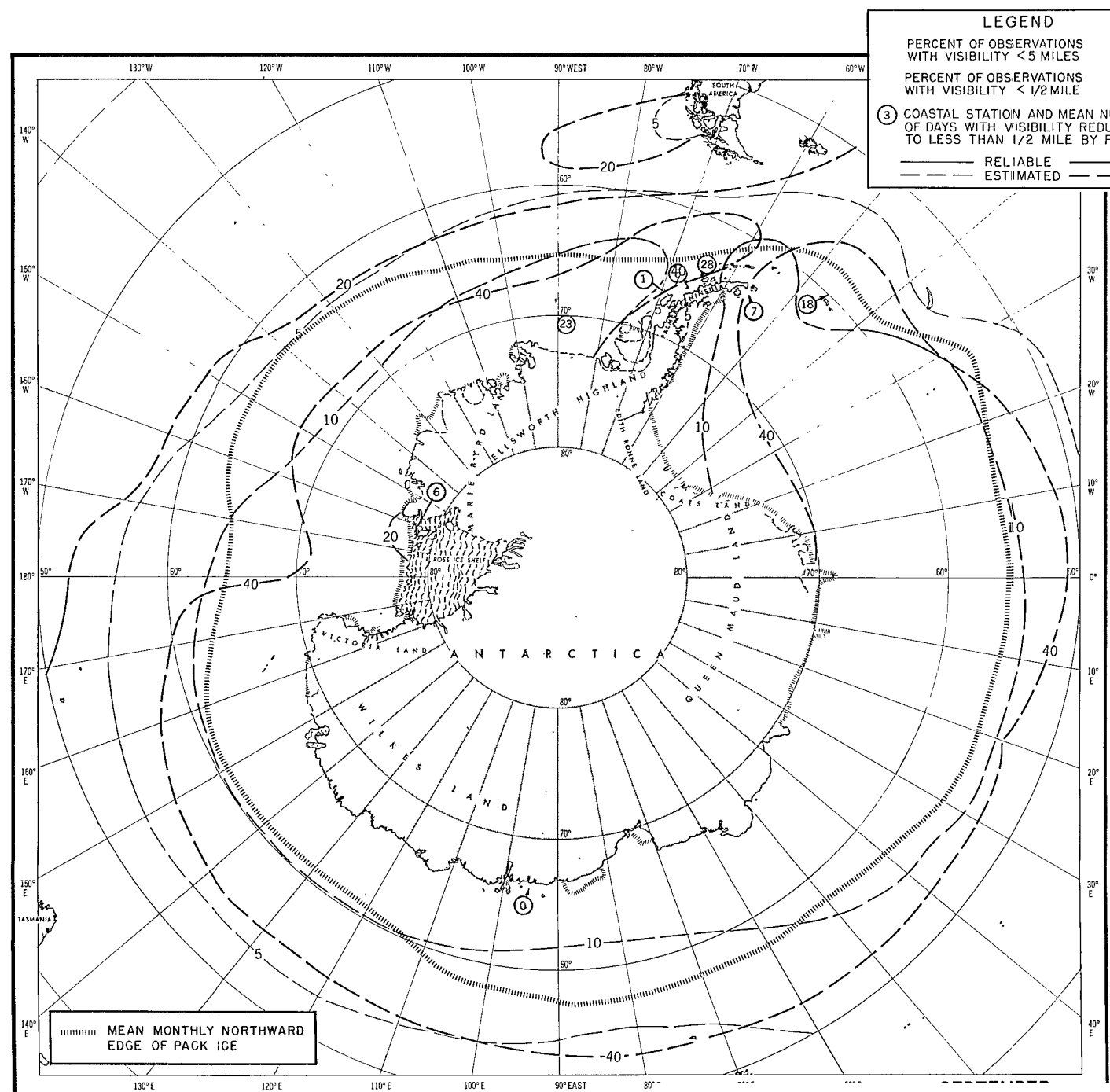
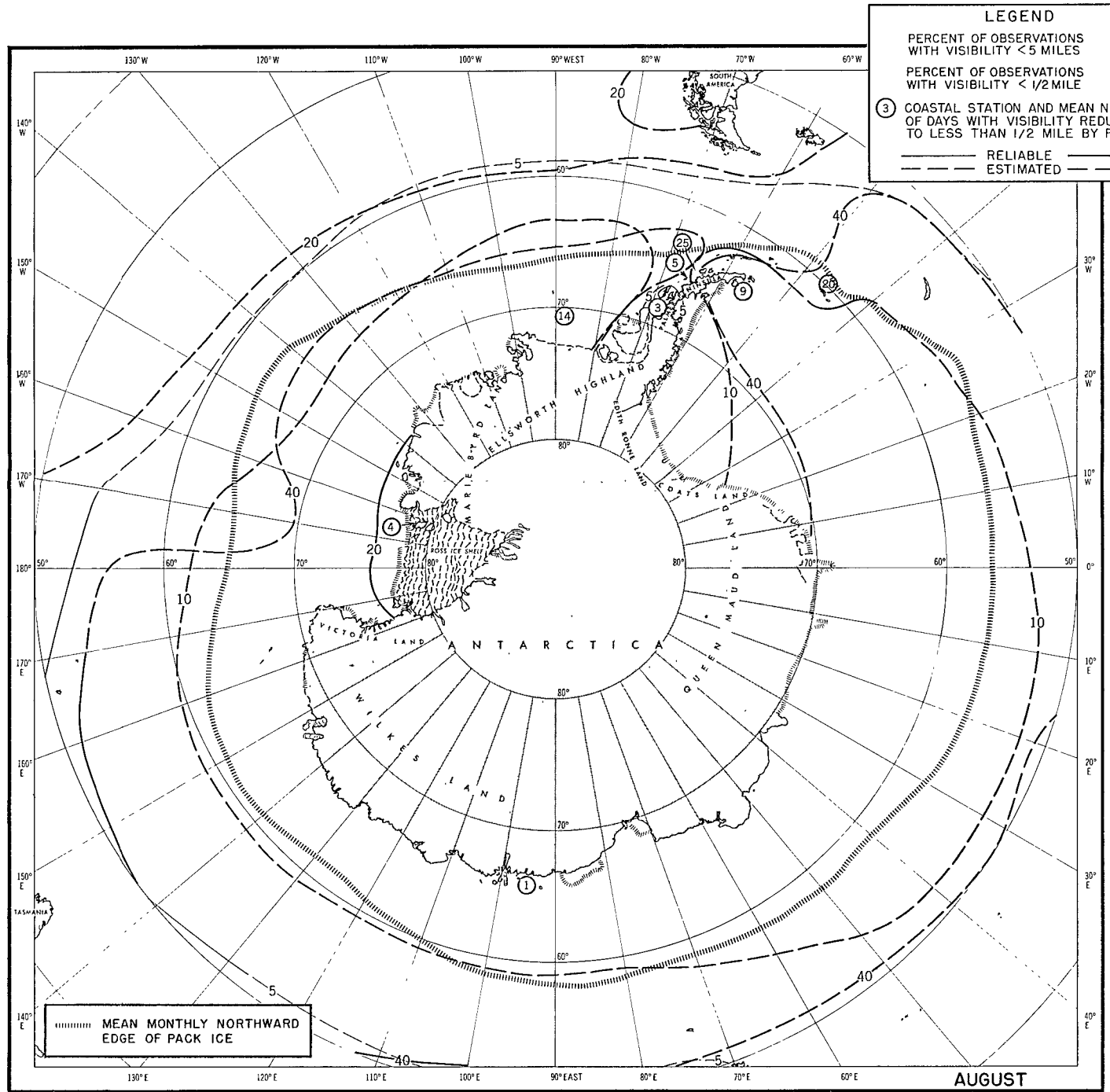
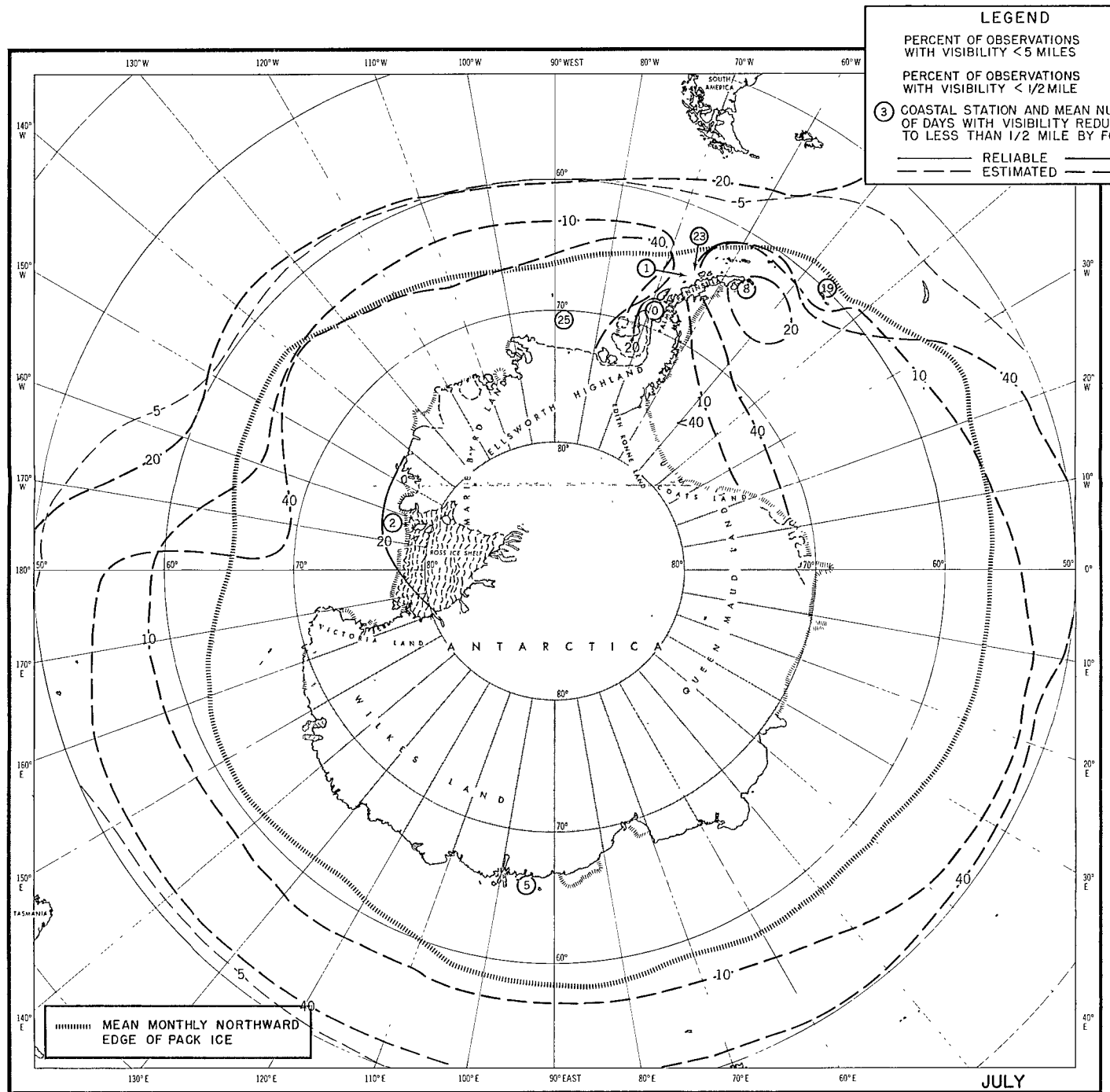
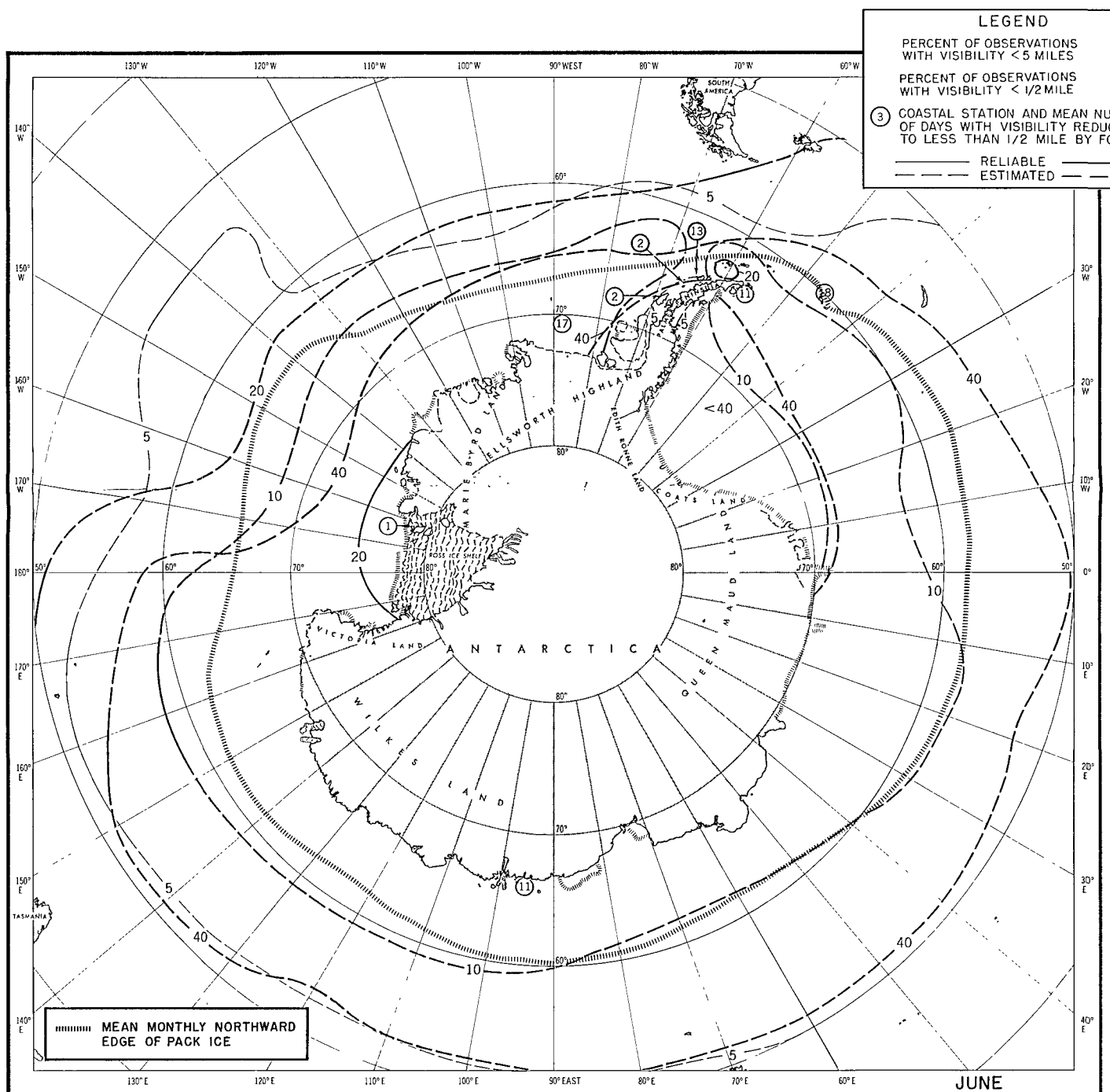
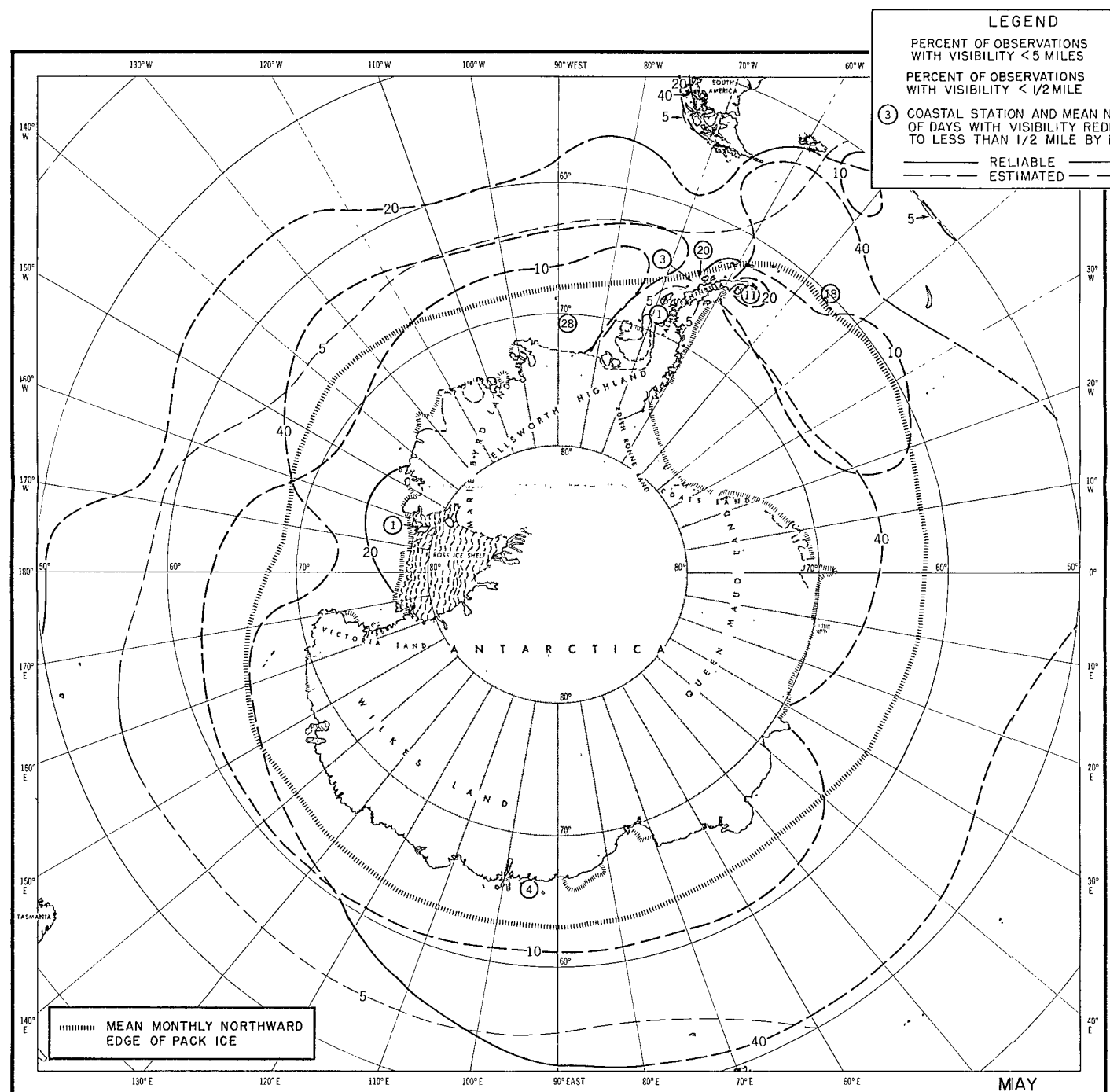
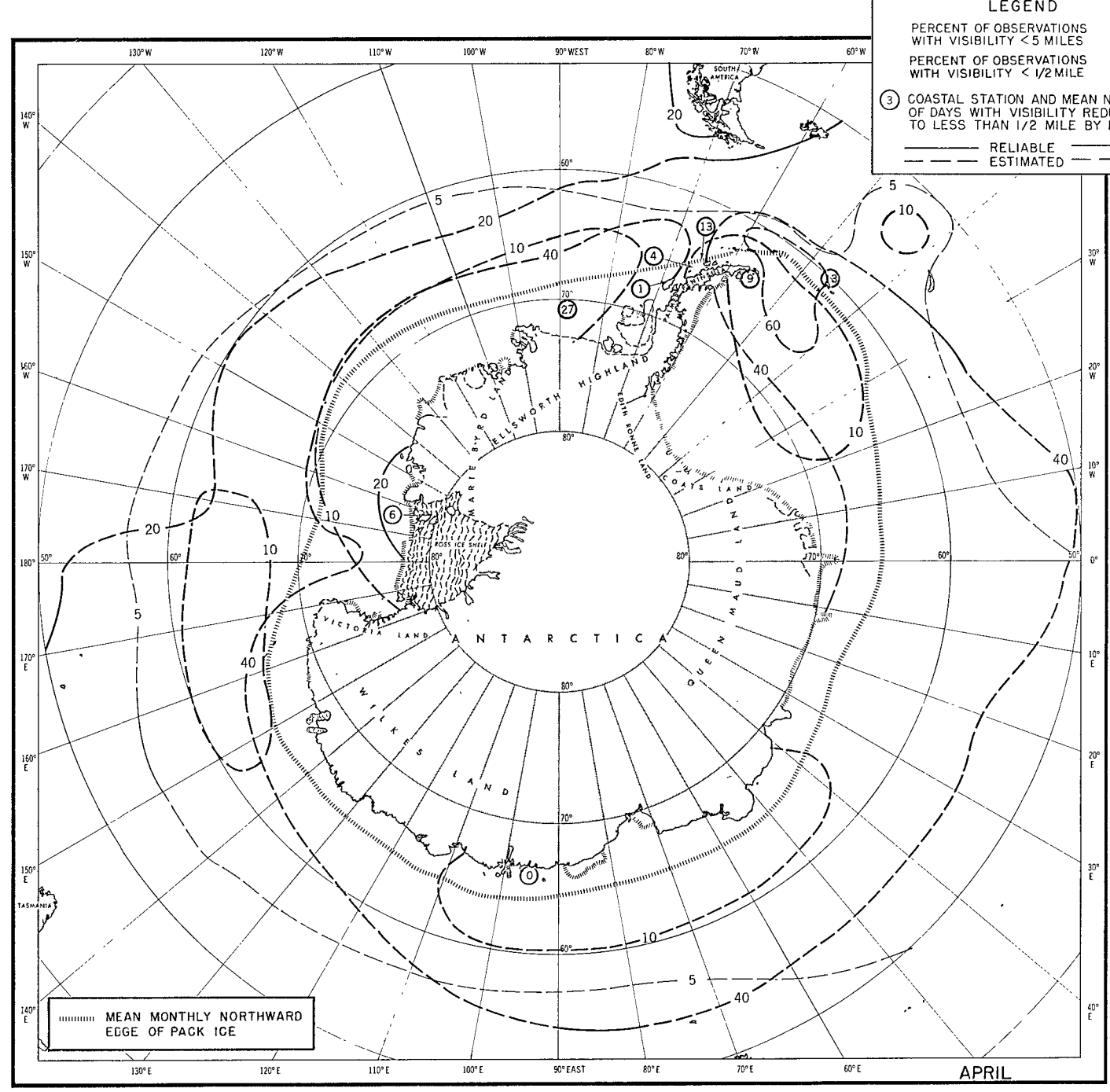
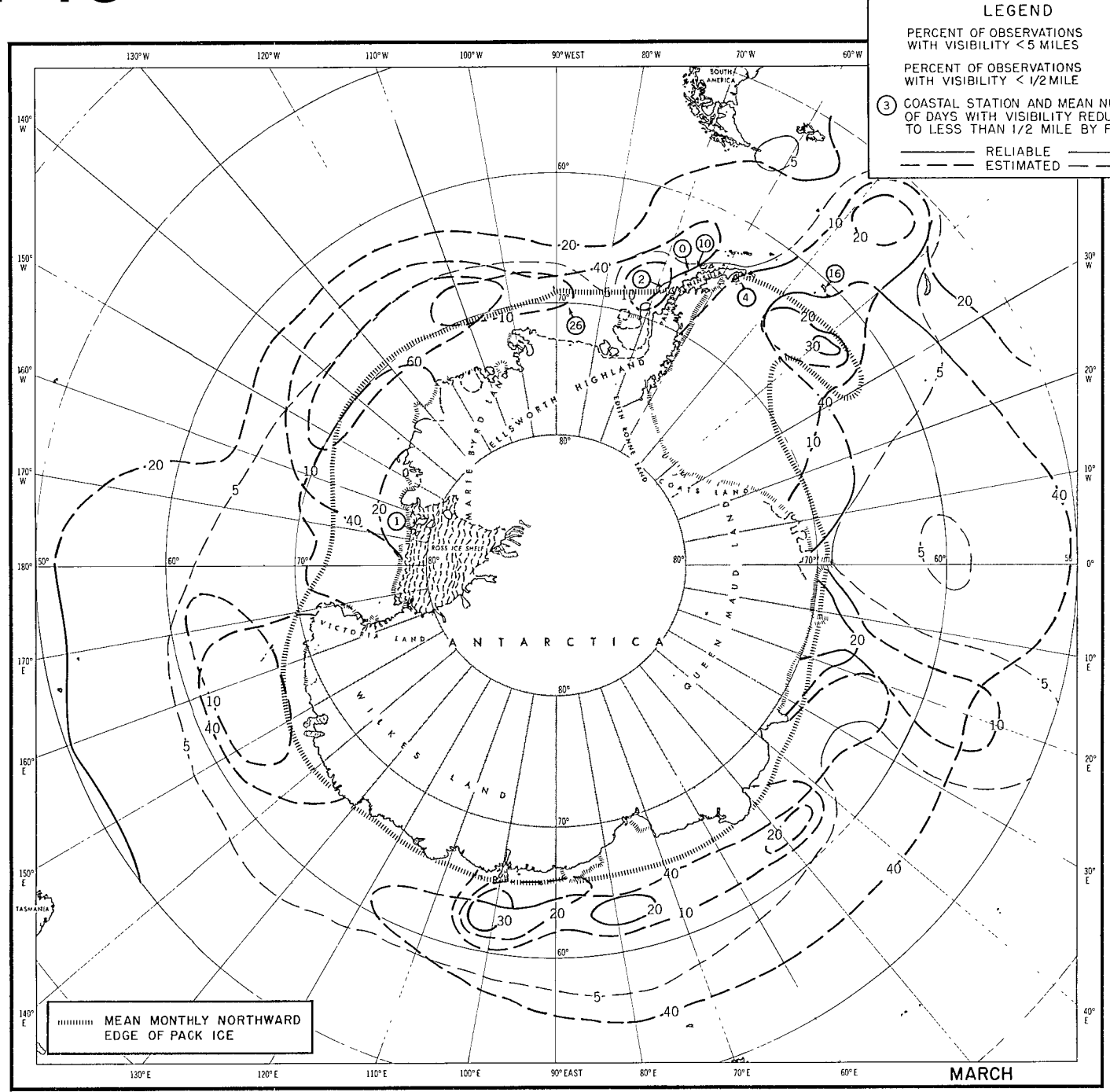
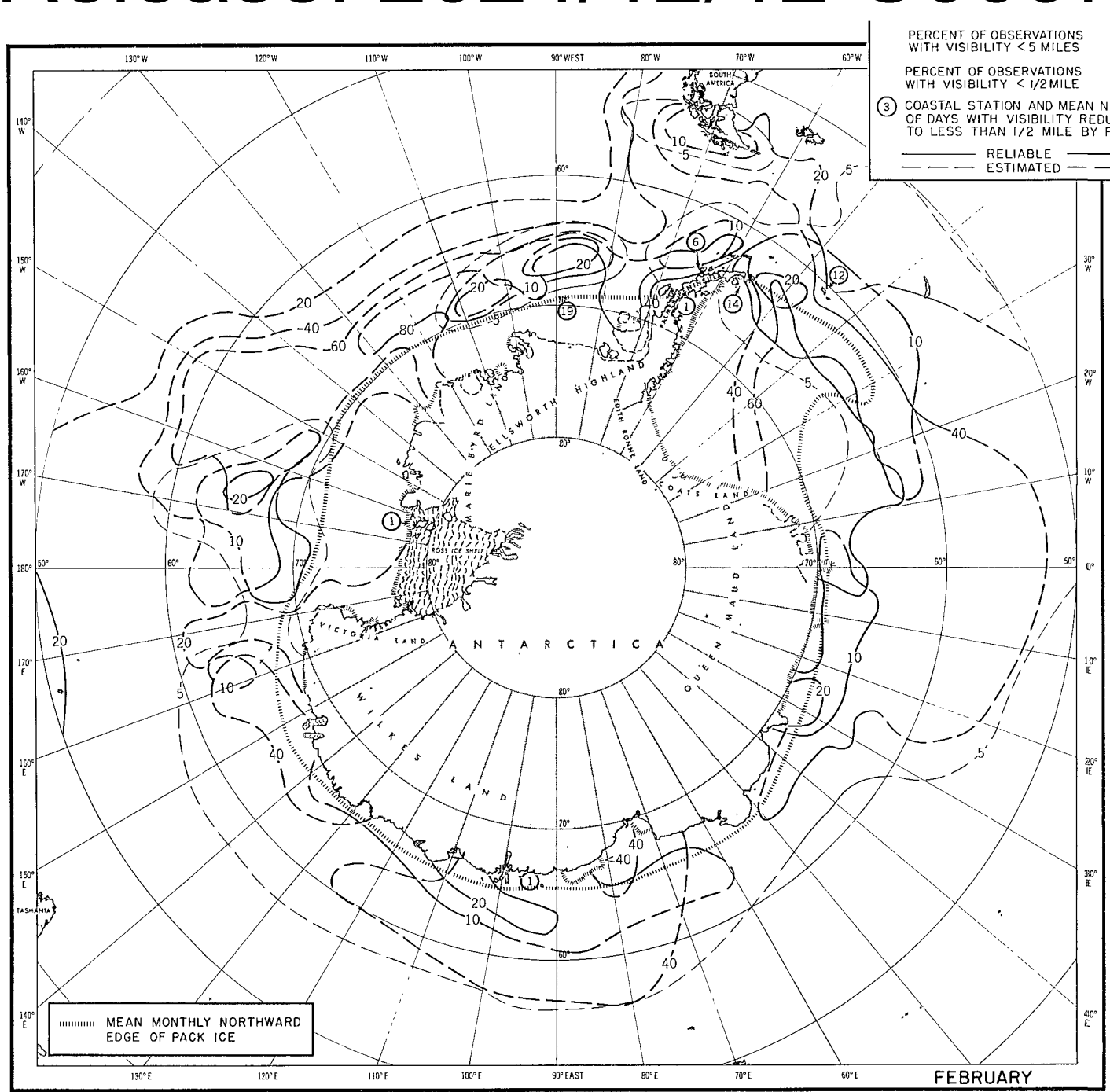
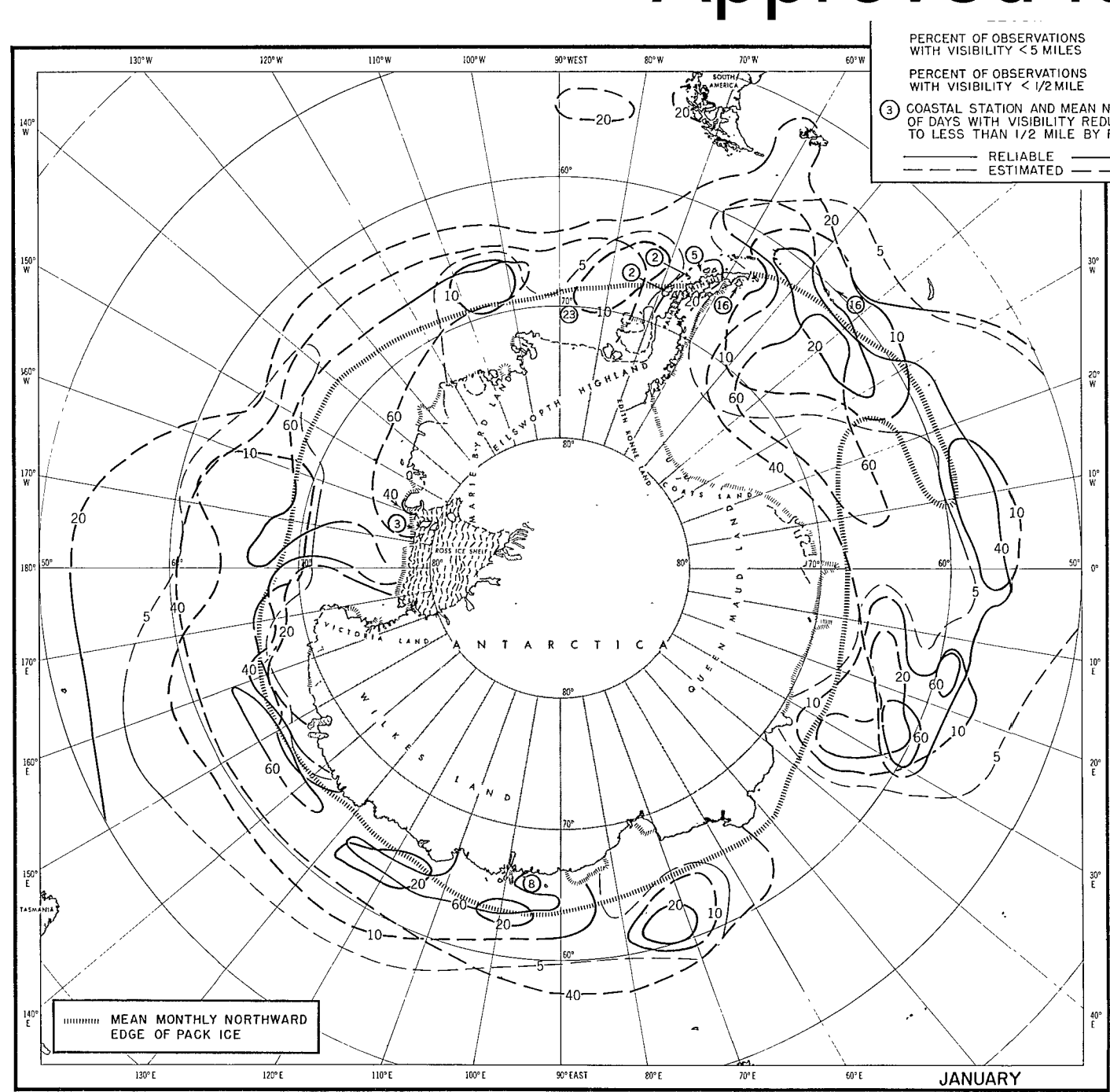


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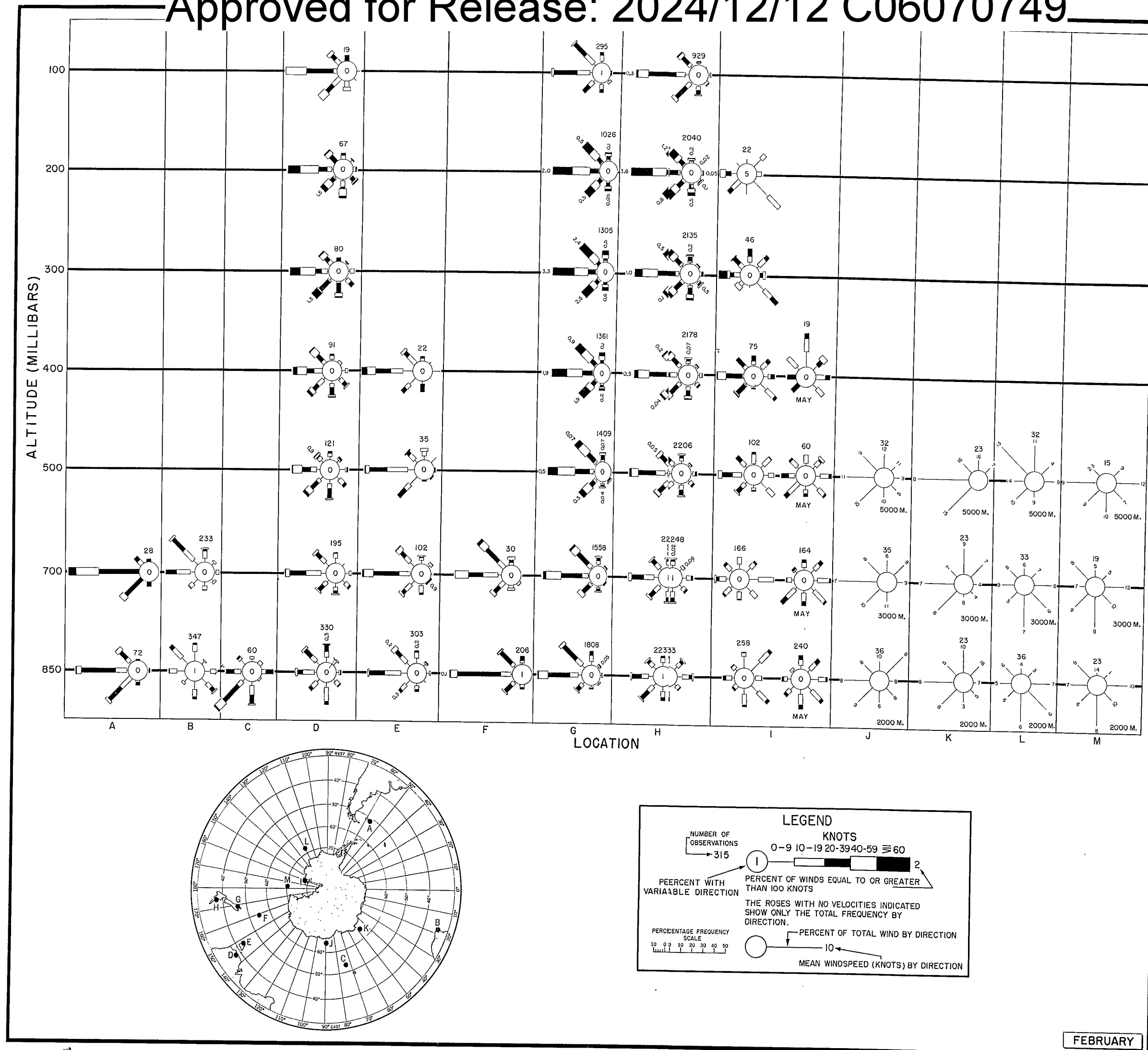




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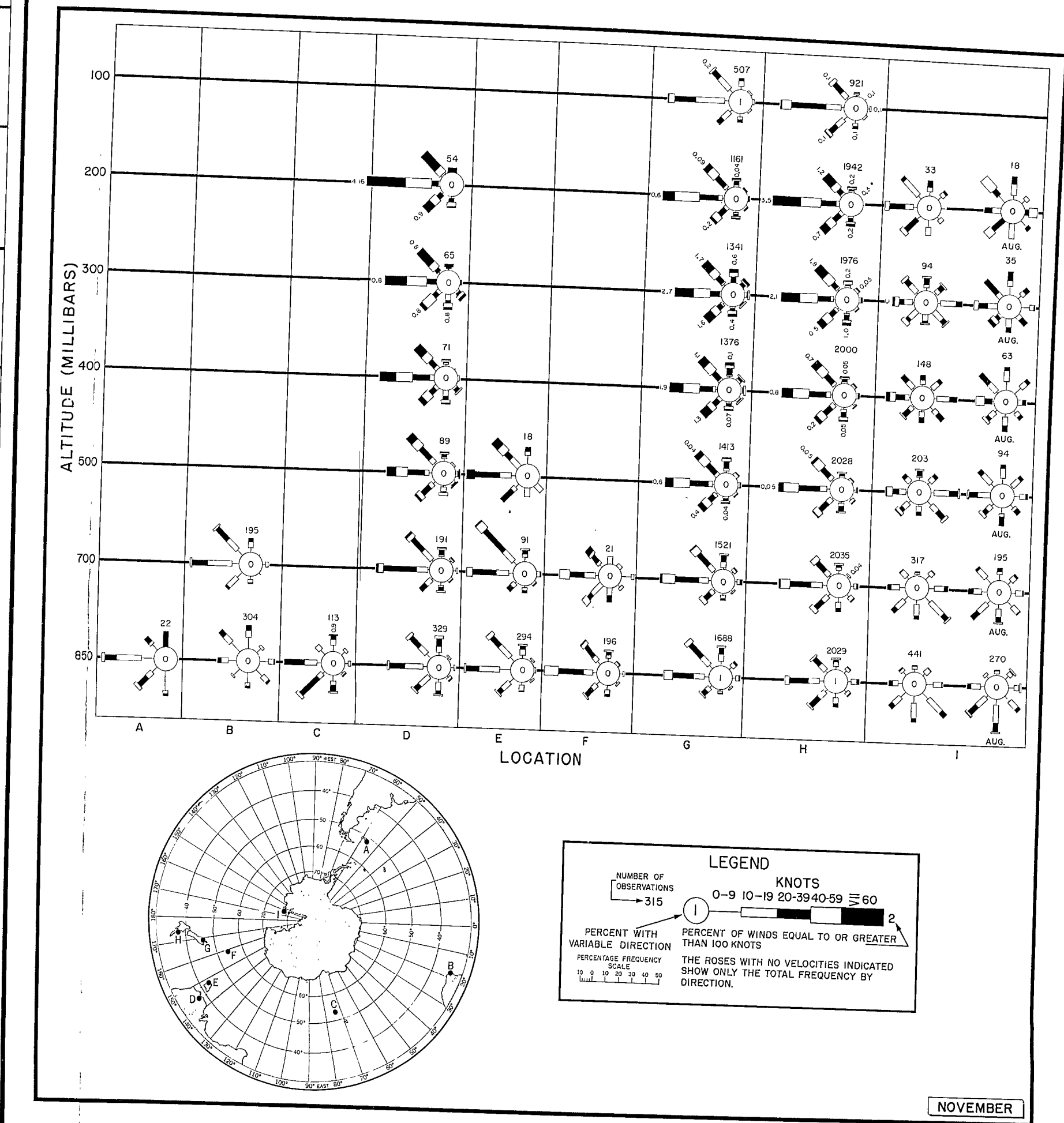


VISIBILITY < 5 MILES AND < 1/2 MILE,
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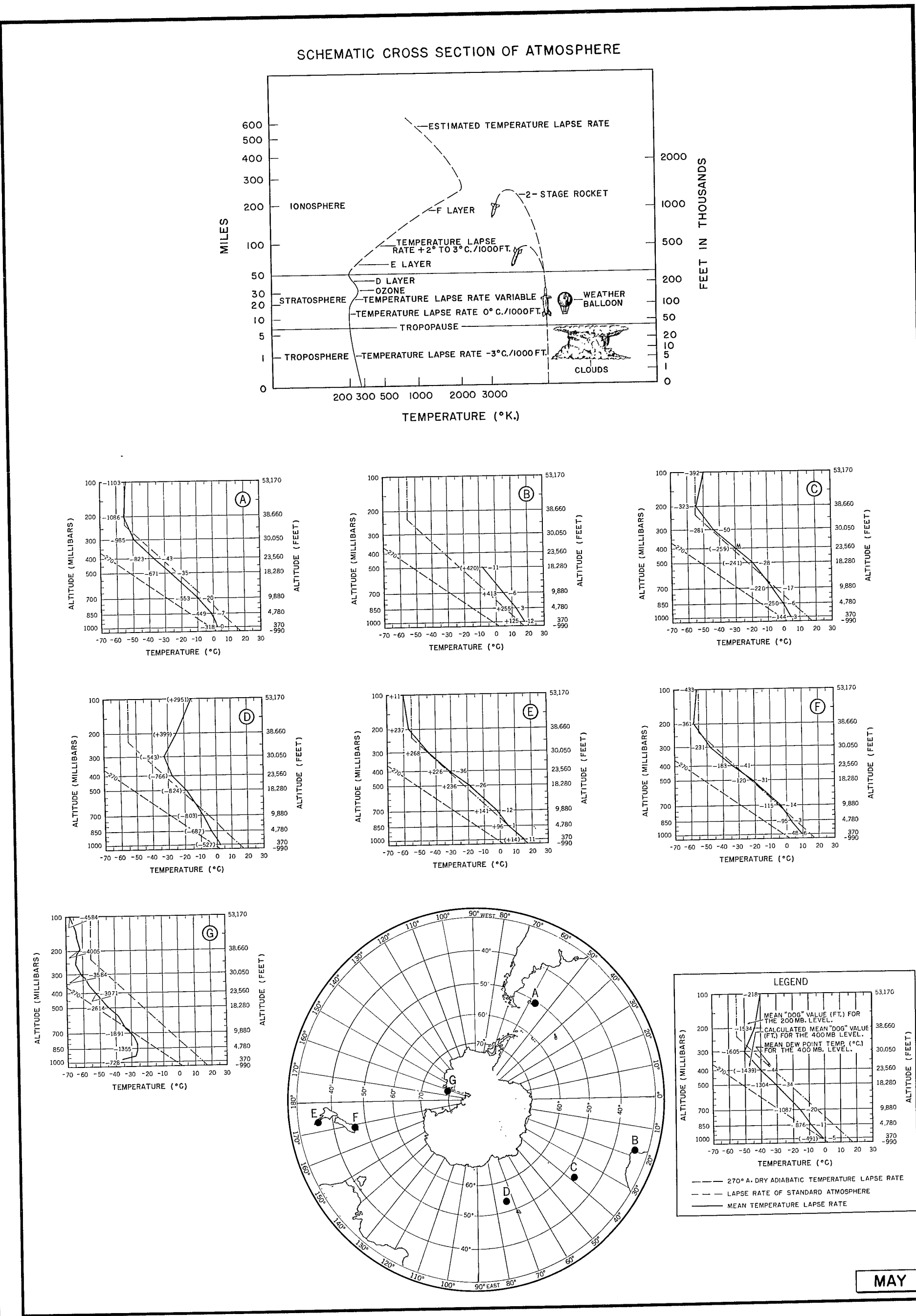
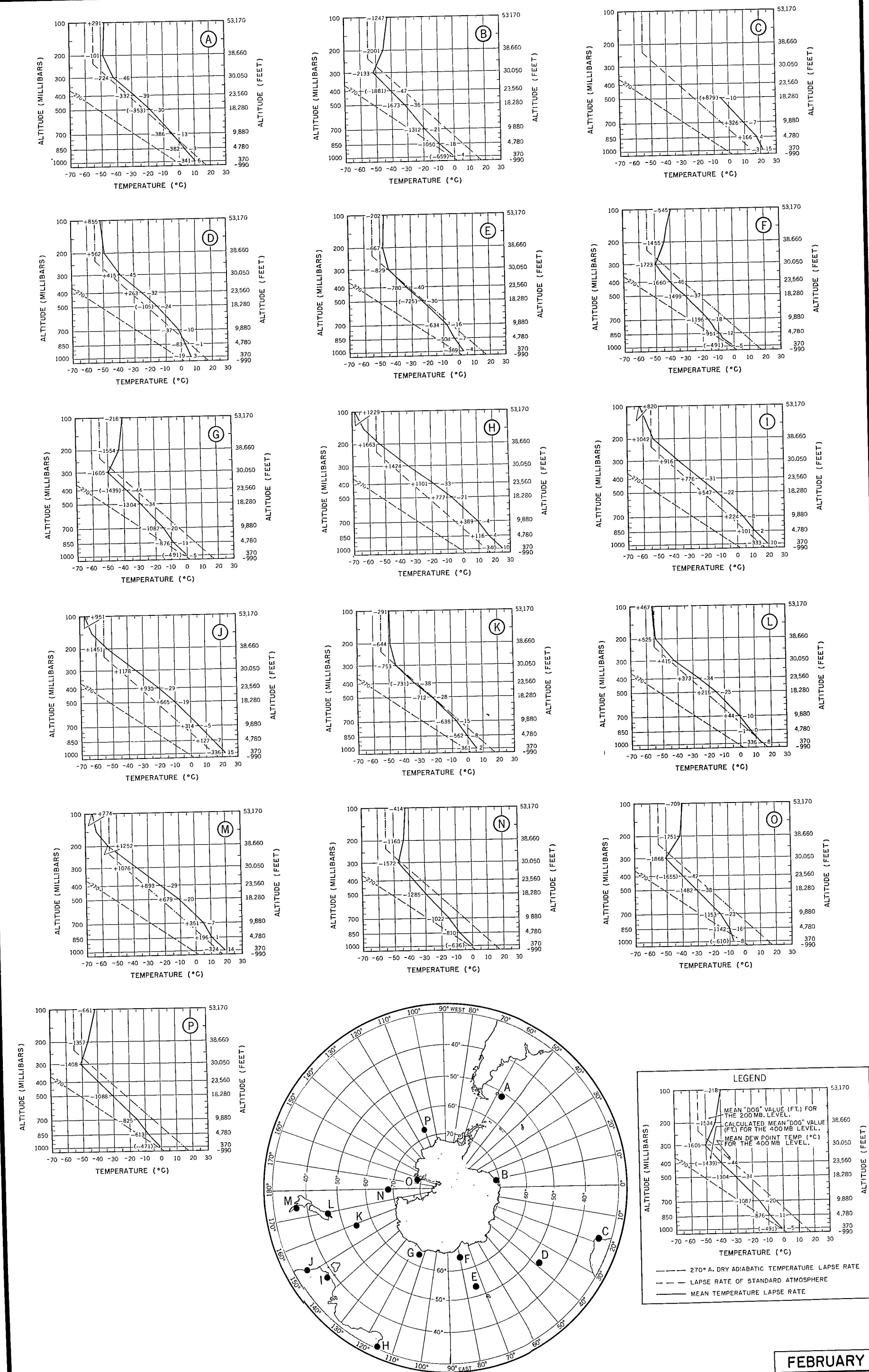


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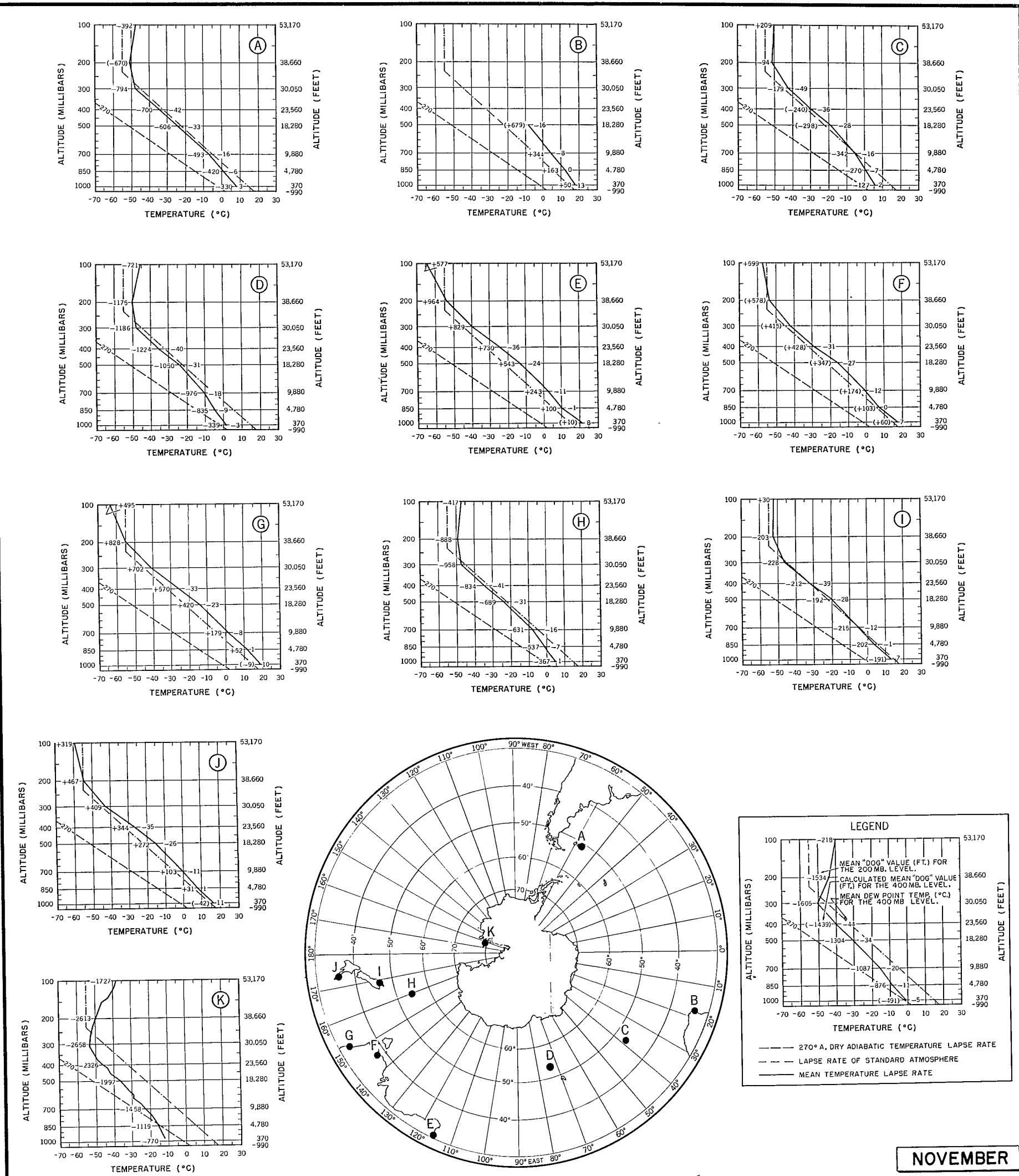
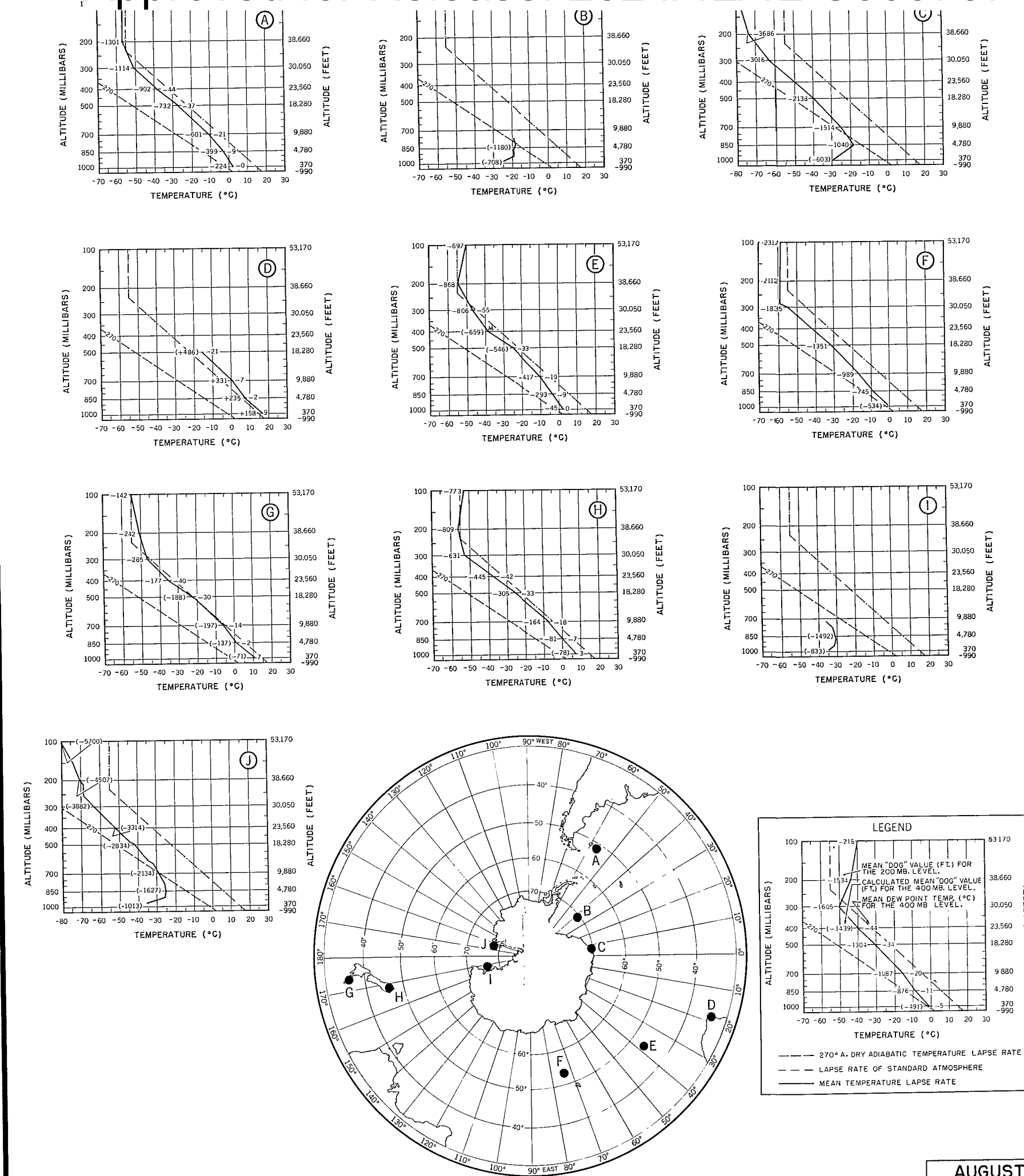
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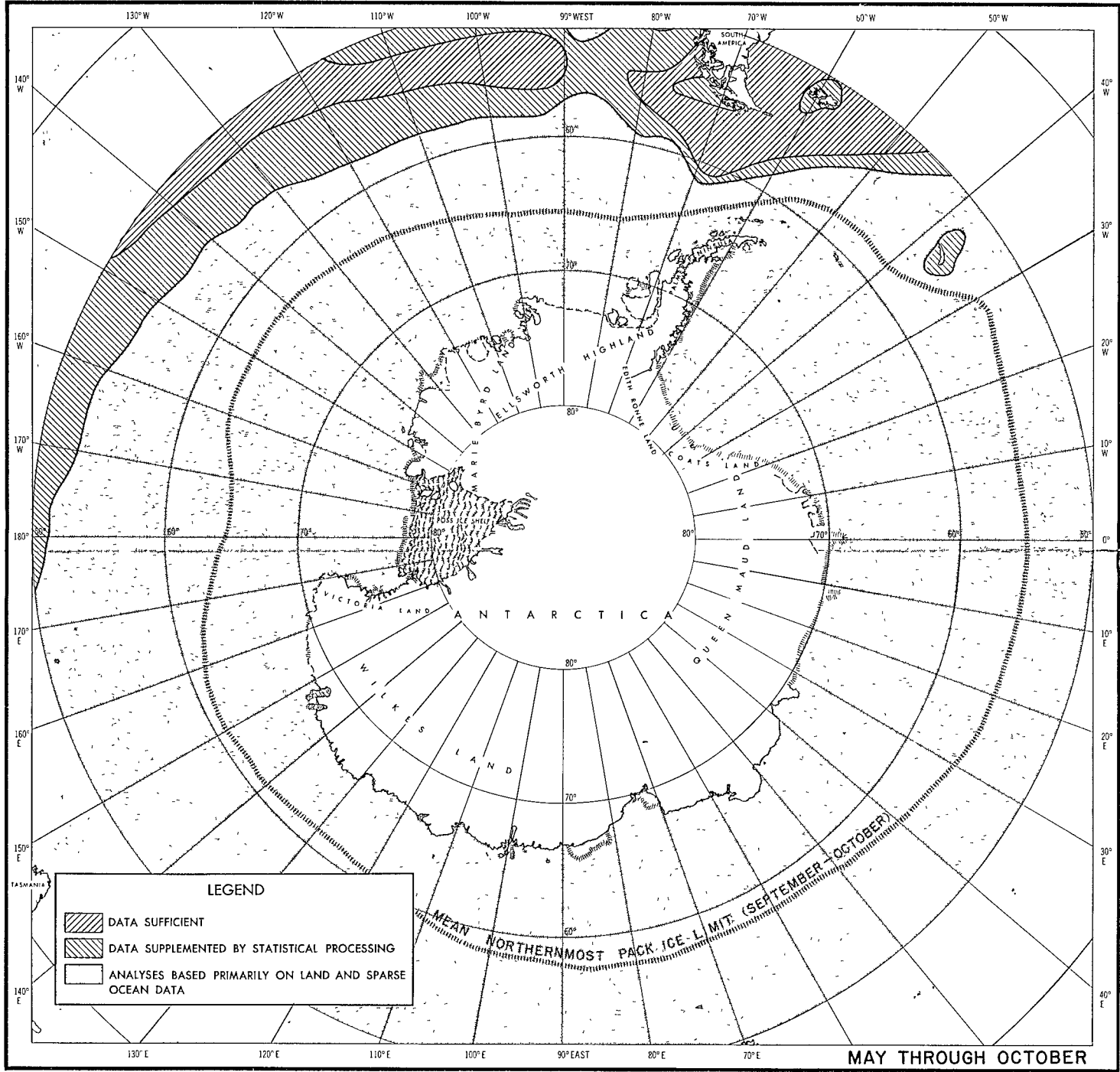


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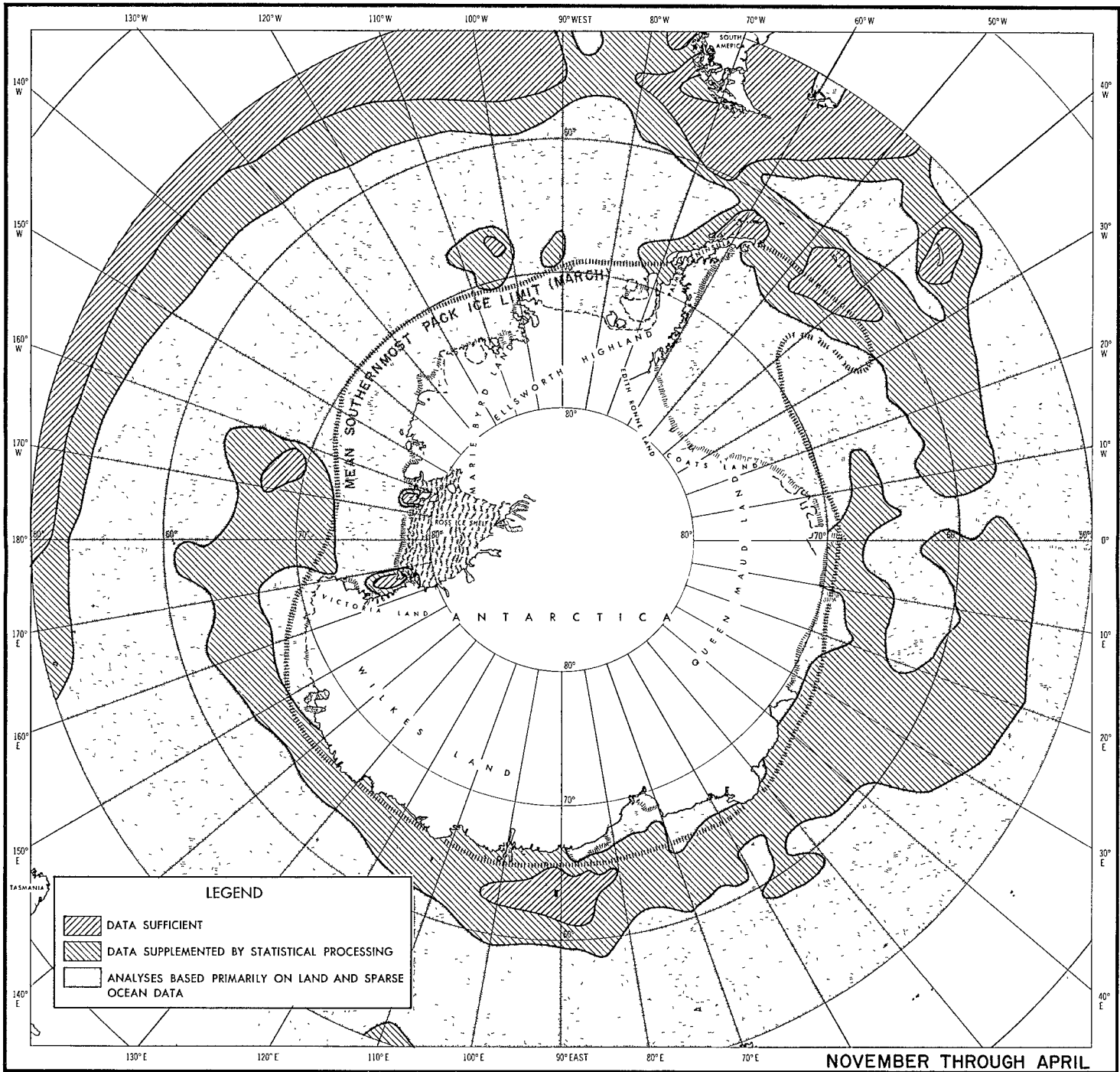


UPPER-AIR SOUNDINGS, AUGUST AND NOVEMBER FIGURE 23-25

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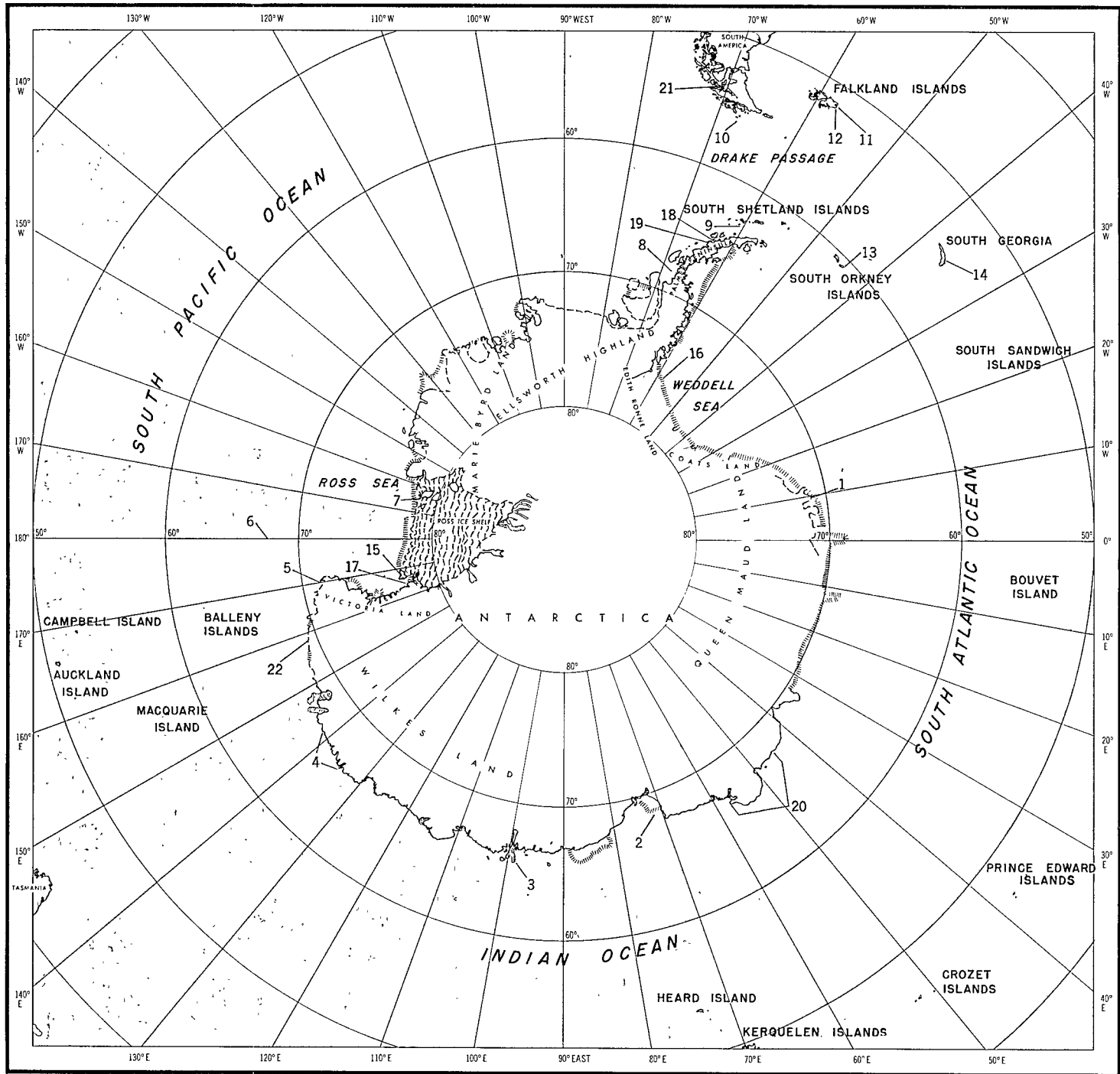
DATA EVALUATION, MAY THROUGH OCTOBER



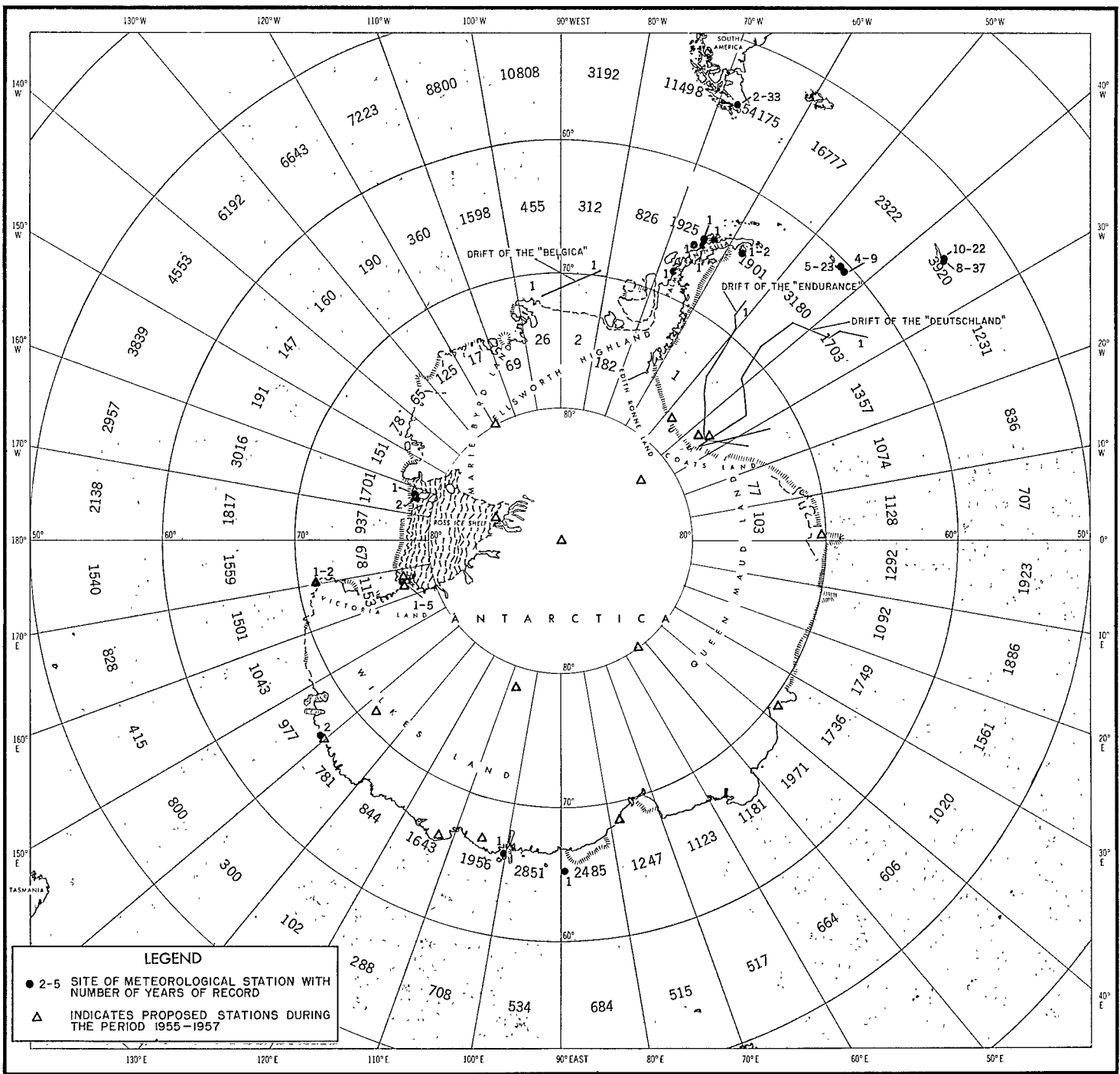
DATA EVALUATION, NOVEMBER THROUGH APRIL

KEY TO PLACES INDICATED ON FIGURE 23-26

NUMERICAL LIST	ALPHABETICAL LIST
1. Cape Norvegia	Adare, Cape (5)
2. MacKenzie Bay	Addie Coast (4)
3. Shackleton Ice Shelf	Argentine Islands (19)
4. Addie Coast	Cumberland Bay (14)
5. Cape Adare	Davies Bay (22)
6. Scott Island	Deception Island (9)
7. Little America	Enderby Land (20)
8. Marguerite Bay	Filehner Ice Shelf (16)
9. Deception Island	Horn, Cape (10)
10. Cape Horn	Laurie Island (13)
11. Cape Pembroke	Magellan, Strait of (21)
12. Port Stanley	MacKenzie Bay (2)
13. Laurie Island	Marguerite Bay (8)
14. Cumberland Bay	McMurdo Sound (17)
15. Mount Erebus	Mount Erebus (15)
16. Filehner Ice Shelf	Norvegia, Cape (1)
17. McMurdo Sound	Pembroke, Cape (11)
18. Port Lockroy	Port Lockroy (18)
19. Argentine Islands	Port Stanley (12)
20. Enderby Land	Scott Island (6)
21. Strait of Magellan	Shackleton Ice Shelf (3)
22. Davies Bay	



LOCATION MAP



TOTAL OBSERVATIONS

~~CONFIDENTIAL~~